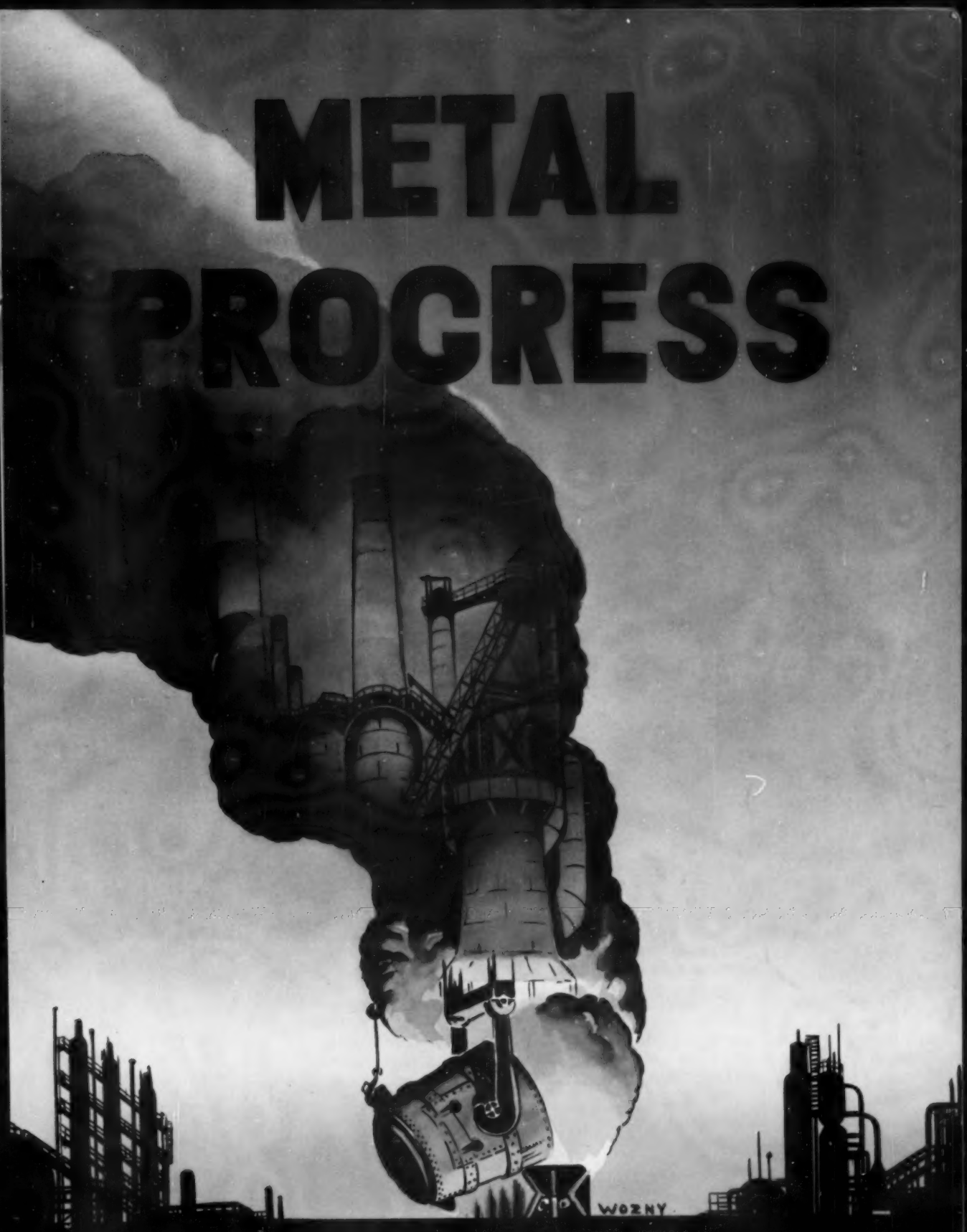
METAL PROGRESS



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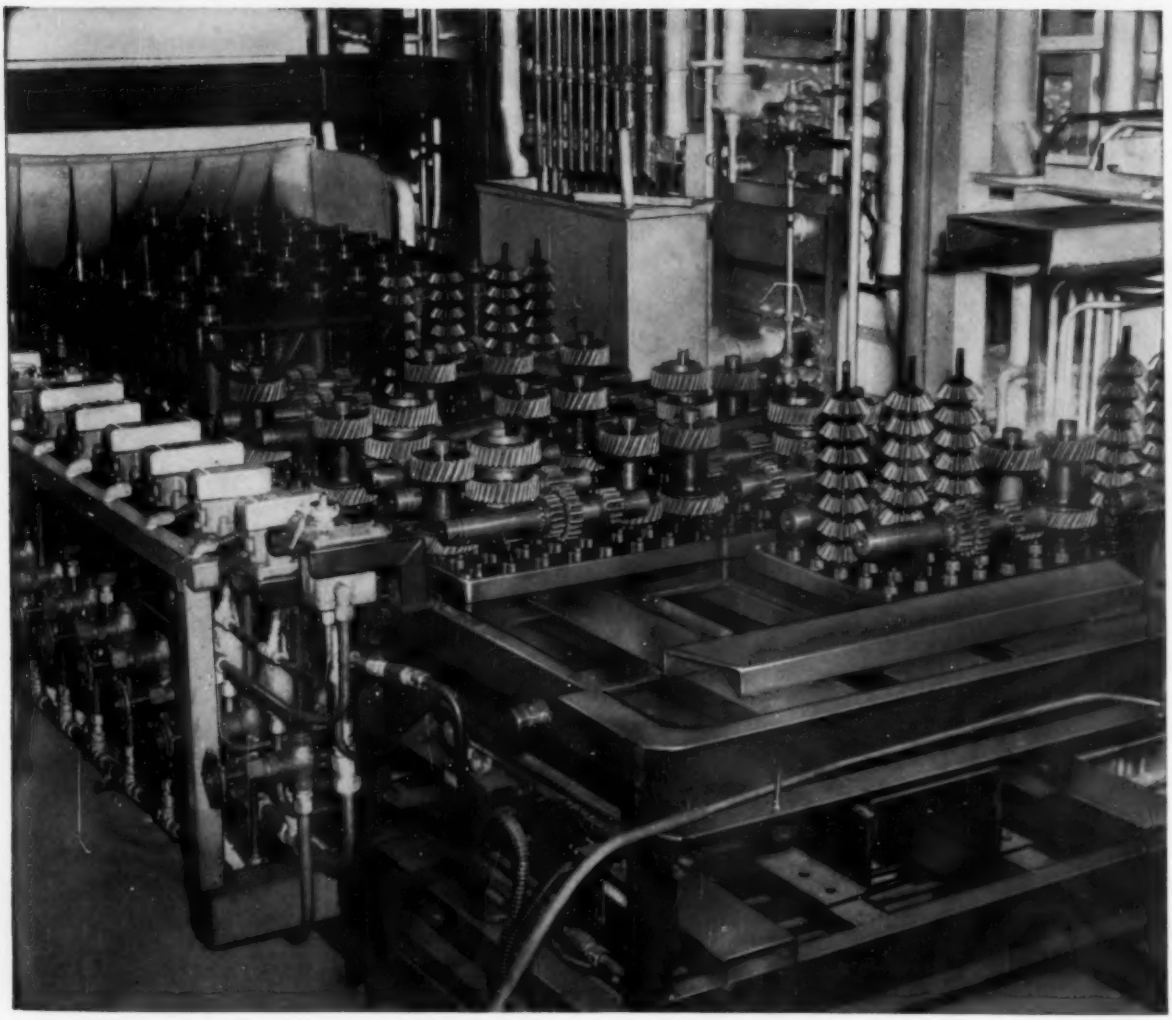

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Metal Progress

Volume 71, No. 2

February . . . 1957

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HAROLD J. ROAST, E. C. WRIGHT and J. L. MCCLOUD
Consulting Editors

Engineering Articles

Insuring Toughness in Forged Gun Tubes, by A. Hurlich and A. F. Jones 65

Composition of steel for large gun forgings is not specified. Heat treatments can be adjusted by the manufacturer to meet required ductility (reduction of area) and toughness (Charpy impact at −40° F.). Soundness is determined by macroetching. (Q23, Q6, J general; ST, 4-1, 15-24)*

Machine Searching of Metallurgical Literature, by Allen Kent, Robert E. Booth and J. W. Perry ..71

The ⊖ research project, only a year old, has already formulated a coding system adaptable to machine feed for various commercial computers and electronic selectors, and several thousand metallurgical abstracts have already been encoded and trial runs made on equipment constructed at Western Reserve University. (A14c)

Taper Heating of Aluminum Extrusion Billets, by A. J. Mueller 76

During extrusion, the temperature of aluminum billets increases by as much as 150° F. To obtain uniform properties of the extrusion, the billet should be preheated with a temperature differential by a special three-section induction coil. (F24, F21b; Al)

General Electric's Research Metallographic Laboratory, by J. B. Newkirk and A. S. Holik 78

A group of eight microscopists and four diffraction experts occupying an efficient layout of 3000 sq. ft. serve the 450 research workers, examining and reporting on about 520 specimens monthly. (M20, M21, M22, M23)

Service Life of Metal Belts in Copper Brazing Furnaces, by Fred L. Hooper 83

Woven wire belts used in copper brazing furnaces last longer if tension is reduced, speed is increased and the belt is reversed periodically. (S21, W12; W29; SS, Ni)

Molybdenum as an Alloy Addition for Titanium, by Harold Margolin 86

A 7% Al, 3% Mo alloy has superior strength-weight properties at elevated temperatures. Molybdenum also has favorable influence on hardenability and oxidation resistance. It seems possible that, with its help, a useful age-hardenable alloy can be developed. (Q general, 2-10; Ti, *Mo*)

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METAL PROGRESS is published monthly by the AMERICAN SOCIETY FOR METALS. Publication office, Mt. Morris, Ill. Editorial, executive and advertising offices, 7301 Euclid Ave., Cleveland 3, Ohio. Subscription $7.50 a year in U.S. and Canada; foreign $10.50. Single copies $1.50; special issues $3.00 . . . The A.S.M. is not responsible for statements or opinions in this publication.

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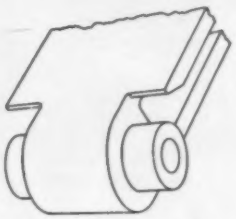

Typical heavy-duty link with cast pin.

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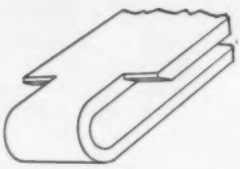

Typical 3″ or 4″ pitch center link of loop-type casting design.

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Types of Furnace Atmospheres, by Curtis H. Vaughan 93

The introductory paper at a joint session of Industrial Heating Equipment Assoc. and A.S.M. at the 1956 Metal Congress. Mr. Vaughan considers six basic sources for protective atmospheres, notes briefly their method of production, and variations in their constitution with variations in the operating equipment and the control settings. (J2k, B25; RM-g)

Thorium's Role in Atomic Power, by John P. Howe 97

This and the following two papers are from the conference on thorium held at the Metal Congress and Exposition with the help of the U.S. Atomic Energy Commission. The complete proceedings, containing 21 papers on various aspects of the metallurgy of thorium, are now being expanded to include information just made available by the new Declassification Guide, and will be published by in book form in the summer of 1957. (T11, C6; Th, U)

Non-Nuclear Uses of Thorium, by W. C. Lilliendahl 104

Principal use of thorium metal in industry is very recent – for alloying with magnesium. Nearly all of the other uses are in the lighting and electronics industry, mostly as oxide. The oxide also has interesting possibilities as a refractory for very high temperatures. (T1, W29, 17-7; NM-h, Th)

A.E.C. Policy on Thorium, by Allan M. Labowitz 108

The "Access Permit Program" for making restricted data available to individuals and organizations, and procedures for private industry interested in participating in work with thorium. (A13p; Th)

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"Nuclear Fuels", edited by David H. Gurinsky and G. J. Dienes, is a not-too-condensed summary of the papers constituting this segment of the Geneva Conference on the Peaceful Uses of Atomic Energy.

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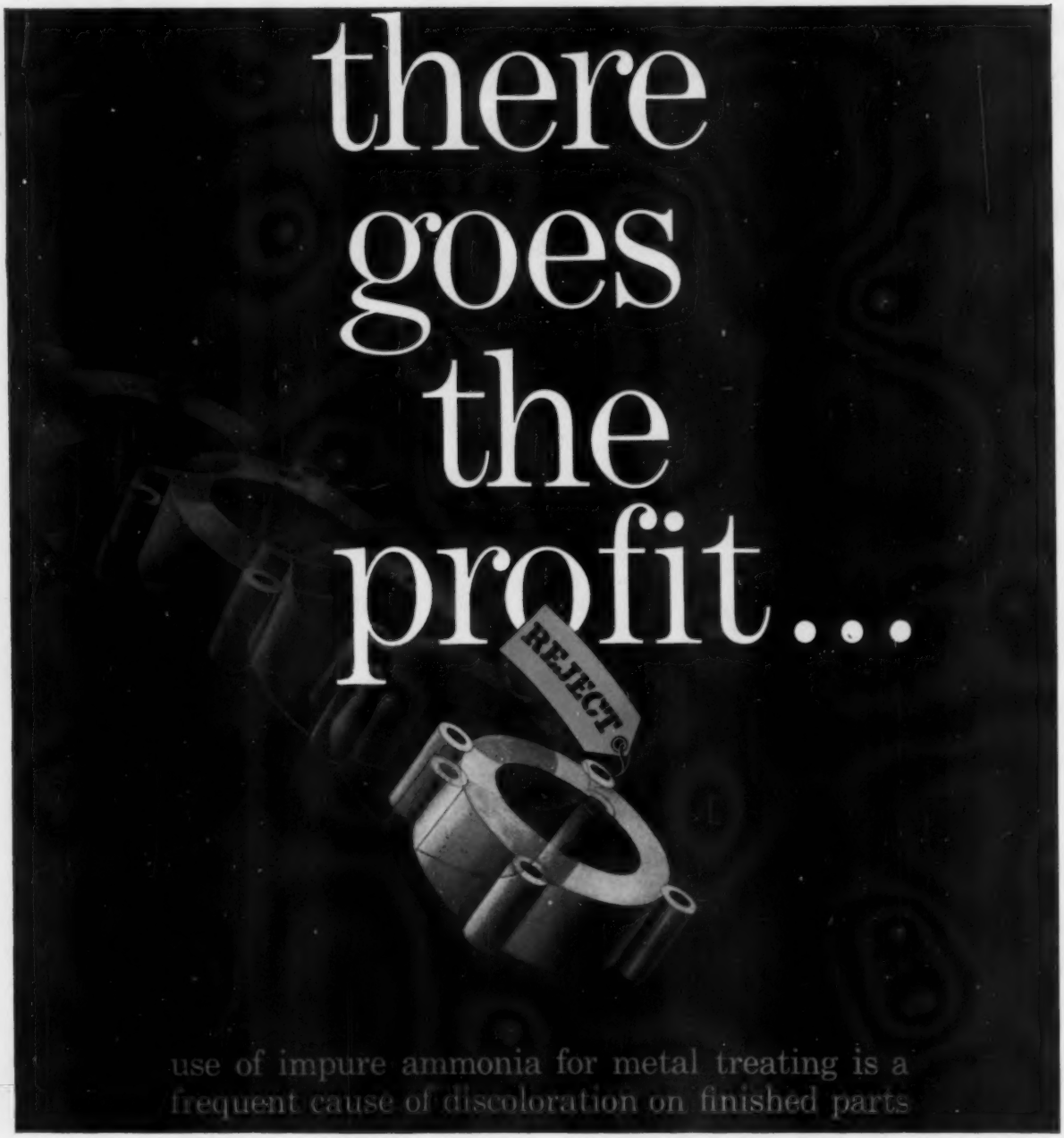
there goes the profit...



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As I was saying...

THERE ARE many fine things associated with being secretary of a big, live technical society like the A.S.M. I'm really fortunate to be so cast, and right now I am enjoying one of those very unusual experiences. So what is it? It is California, or should I say, "The Western Metal Congress and Exposition", which is coming off here in Los Angeles, March 25 to 29, 1957.

I recall the first Western Show in Los Angeles in February of 1929. It was a fair-sized undertaking and proved highly successful, with splendid attendance and a good program. In truth, there has never been a dud in the West (or in the East for all that) so this coming tenth Congress has all the characteristic earmarks of another successful event.

The tremendous progress and advancement of these western activities have been directly proportionate to the growth and industrial advancement of the western states. While all the western states now produce 11% of the national economy, California alone produces 90% of the western states' share. When the airframe, missile, electronic and general metal producing and fabricating industries settled in Southern California, the Western Metal Congress and Exposition became an important necessity.

The response from manufacturers to the invitation to exhibit has been overwhelming. The entire space facilities of the huge Pan-Pacific Auditorium and four additional pavilions have been reserved. More than 400 exhibitors will display their products in operation and more than 2500 of the leading technical and mechanical engineers will be in the exhibitors' booths to explain their products and processes.

The technical programs will rival in interest and information the best programs produced at any of the eastern conventions. The sessions have been aimed directly to and for the western metal industries, and the thousands who will attend are all sure to take away some valuable ideas.

The western sections of 36 national technical societies have been invited and accepted the opportunity to become cooperating societies in the Congress and the Exposition. The membership of the 36 western sections totals 32,455.

Five of the societies will have technical programs presented at the headquarters, the Ambassador Hotel. They are the American Society for Metals, the American Welding Society, Society for Nondestructive Testing, American Institute of Mining, Metallurgical and Petroleum Engineers — Metals Branch, and the Industrial Heating and Equipment Association.

Bill Ward of Lockheed is the chairman of the A.S.M. program committee and he and his committeemen are doing a magnificent job. A complete program of the event will be carried in *Metal Progress* next month.

So with the great progress and glowing prospects of another successful Western Metal Congress and Exposition, you can easily recognize that being Secretary of the live and active A.S.M. has its many compensating and rewarding features.

Cordially,

Bill

W. H. EISENMAN, *Secretary*
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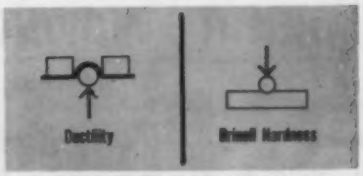

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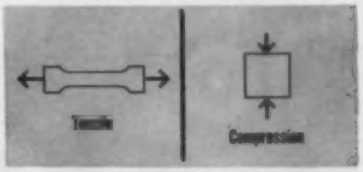

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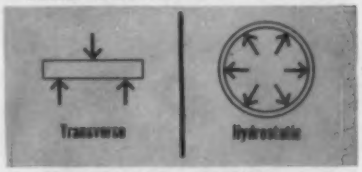

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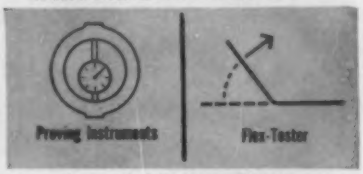

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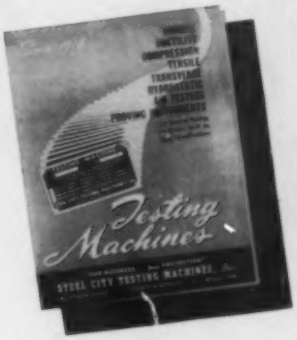

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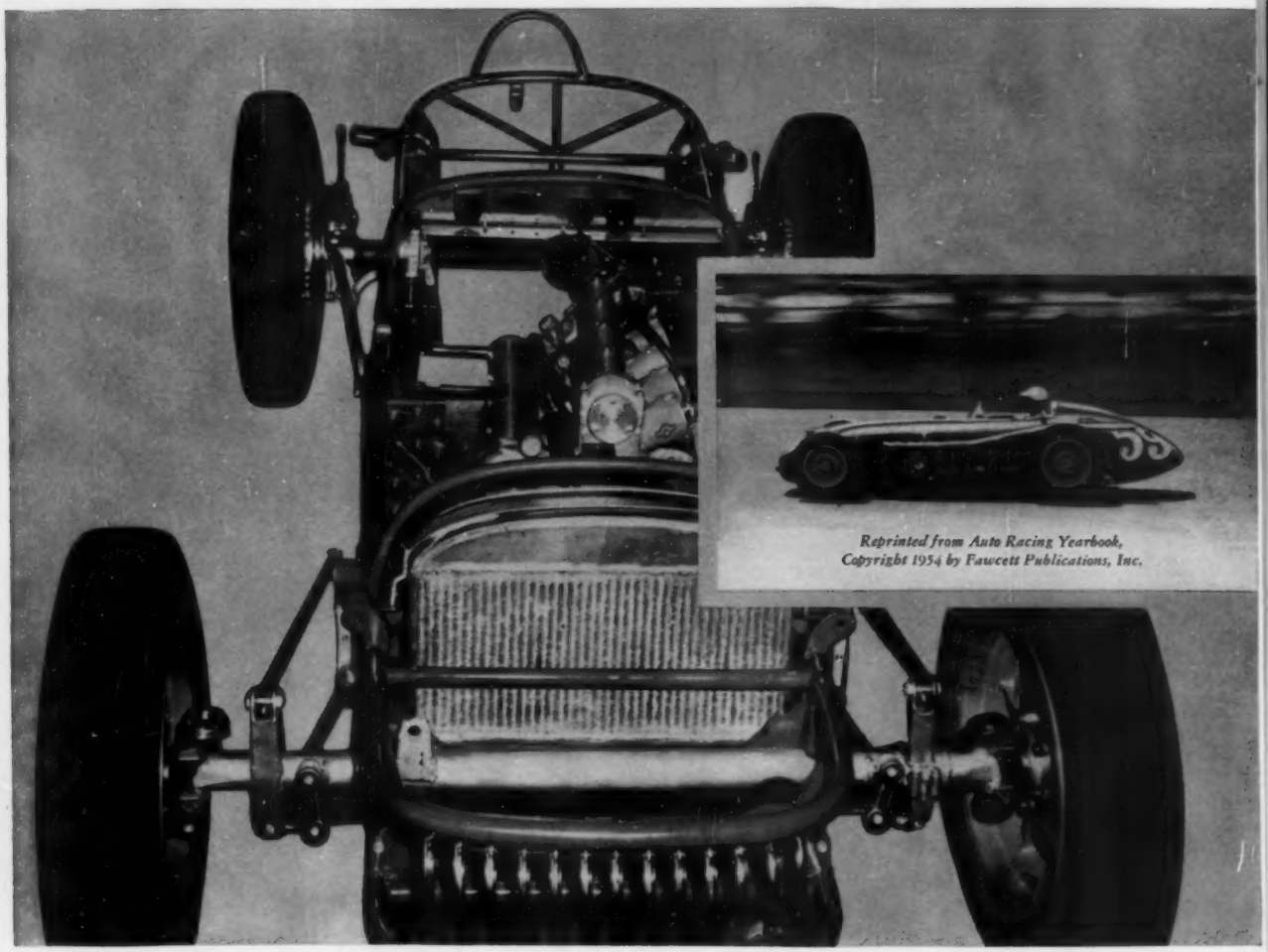

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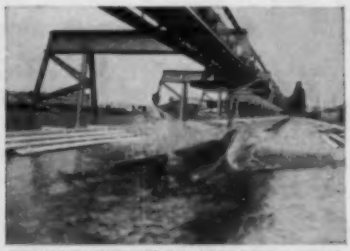

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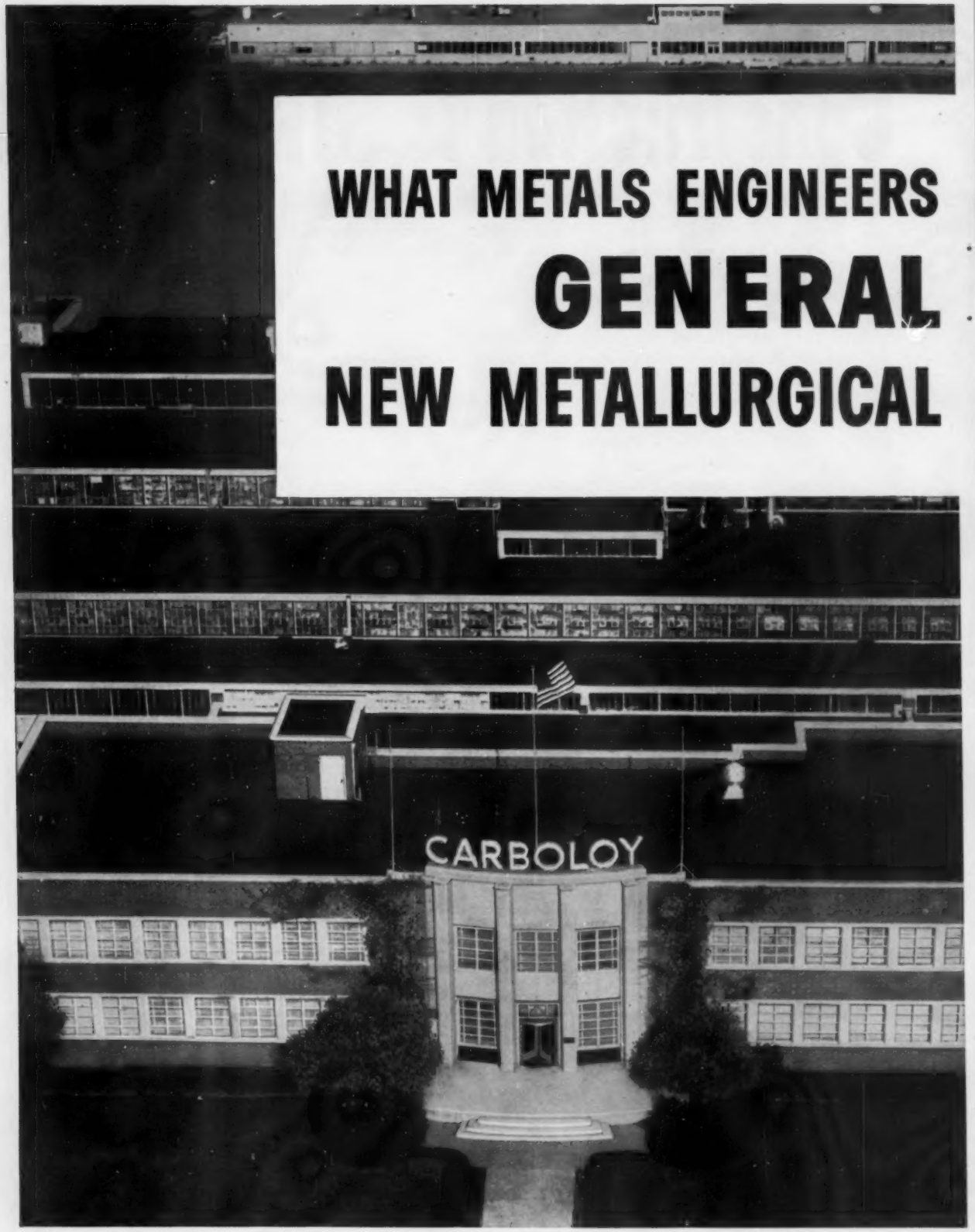

Headquarters of the Metallurgical Products Department of General Electric Company, 11167 E. 8 Mile Ave., Detroit 32, Michigan. Carbides, vacuum-melted alloys, and hevimet are made here. G-E permanent magnets and specialty resistors are manufactured in the Edmore, Mich., plant.

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Thus, the new departmental name symbolizes the broadened scope of this Department's activities . . . a scope which will have far-reaching effects for metals engineers in every phase of industry.

For General Electric – through its Metallurgical Products Department and the G-E Research Laboratory – is carrying on fundamental investigations which are extending the frontiers of metallurgy.

For example, the process which created G-E man-made diamonds may yield new structural and design materials which do not even exist in nature. And General Electric's work in powder metallurgy, metallic oxides, and semiconductors – which produced many of the products mentioned above – has a fascinating future all its own.

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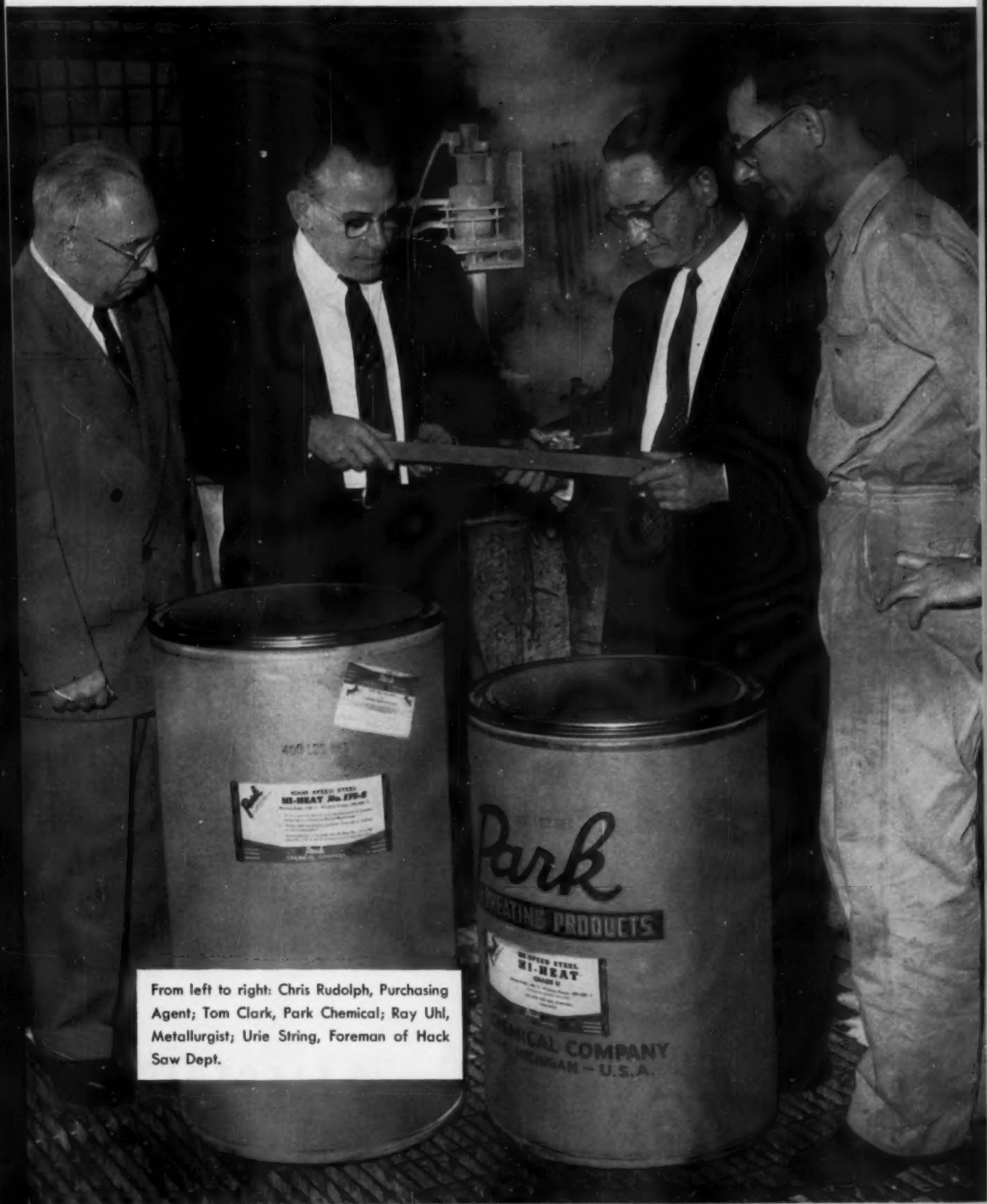

From left to right: Chris Rudolph, Purchasing Agent; Tom Clark, Park Chemical; Ray Uhl, Metallurgist; Urie String, Foreman of Hack Saw Dept.

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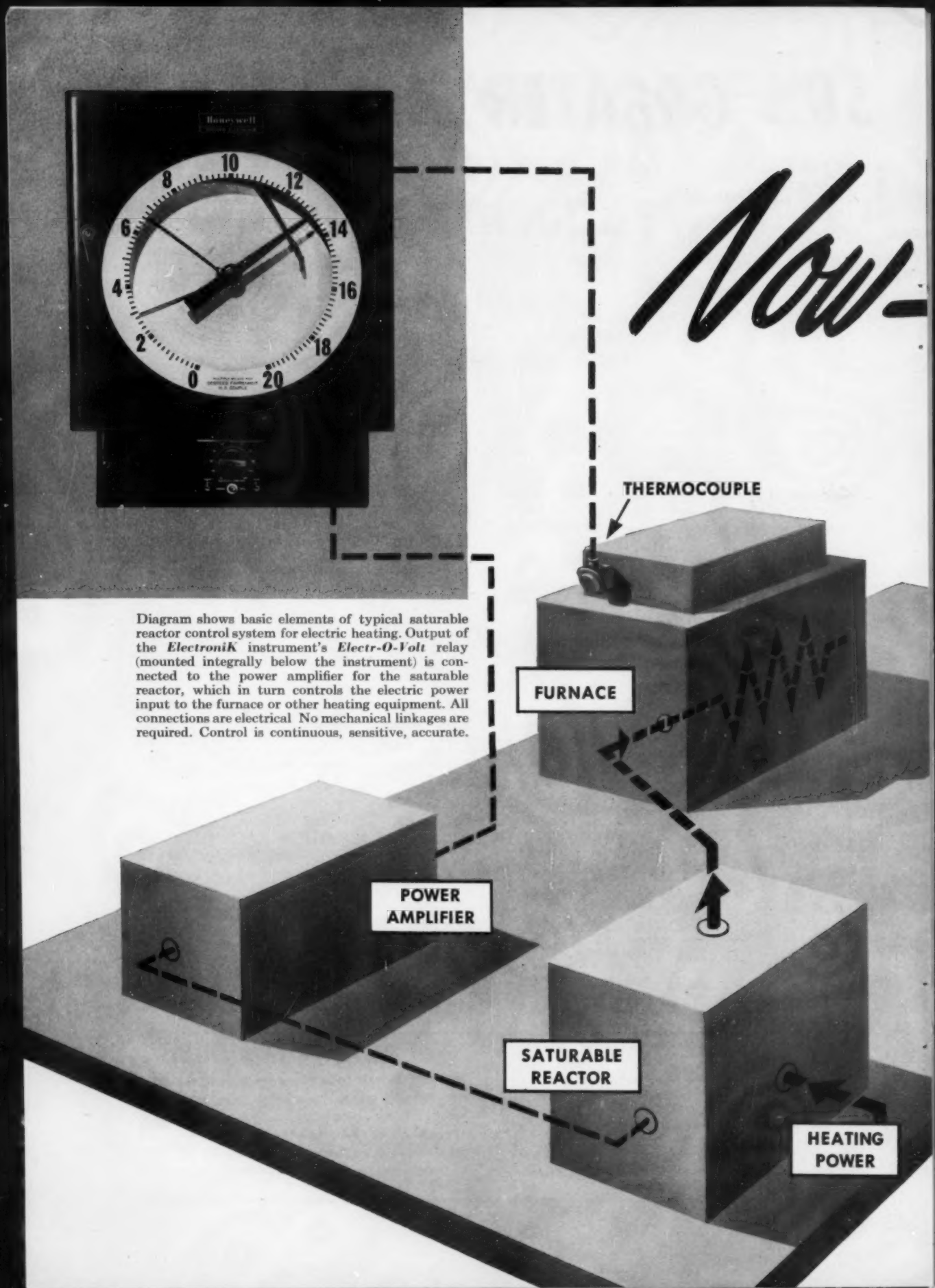

Diagram shows basic elements of typical saturable reactor control system for electric heating. Output of the *ElectroniK* instrument's *Electr-O-Volt* relay (mounted integrally below the instrument) is connected to the power amplifier for the saturable reactor, which in turn controls the electric power input to the furnace or other heating equipment. All connections are electrical No mechanical linkages are required. Control is continuous, sensitive, accurate.

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ElectroniK instrumentation with Electr-O-Volt* relay provides continuous throttling in saturable reactor control systems

You can now regulate temperatures of electrically heated furnaces, ovens, and similar processing equipment within exceptionally close tolerances, by using an advanced *ElectroniK* control system in conjunction with saturable reactors. This type of control eliminates the abrupt surges of power and the expense of contact replacement which are frequently objectionable factors of on-off or pulsed electric control.

Continuous control action. The *Electr-O-Volt* relay, actuated by the *ElectroniK* instrument, provides continuously variable control input to the saturable reactor power amplifier. This arrangement gives true proportional-plus-reset control action, which adjusts heat input to compensate for size of load, ambient temperature and other transient and long-term variations in heat demand.

Completely electronic. The system has no mechanical linkages, contactors, or other complex moving parts. Its high speed and sensitivity give the precise control required by modern processes.

Broad range of use. *ElectroniK* control for saturable reactors is applicable to high-temperature heat-treating furnaces, reaction vessels and many other types of electrically heated equipment. It makes possible smooth, finely-adjusted regulation of electric power at high efficiency.

For a discussion of how this control can be applied to your specific problems, call your local Honeywell sales engineer. He's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario. *Trademark

● **REFERENCE DATA:** Write for Catalog 1531, "*ElectroniK* Controllers," and for new Bulletin 8420, "*Electr-O-Volt* Relay."

MINNEAPOLIS **Honeywell**

BROWN INSTRUMENTS

First in Controls

Speed for
aluminum extrusion . . .

Westinghouse

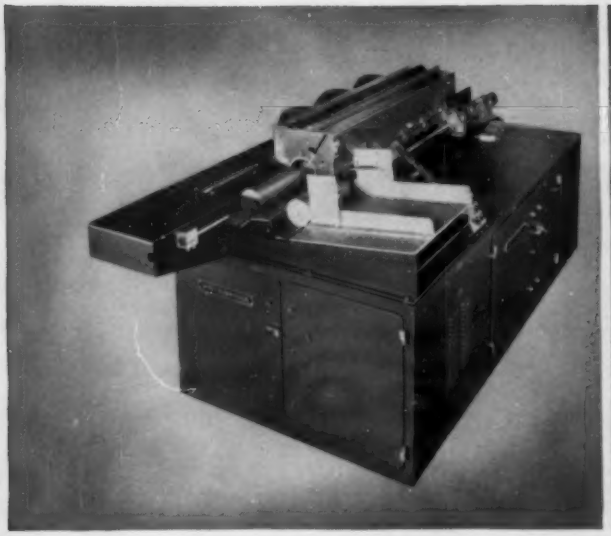
1. Greater efficiency in aluminum billet extrusion results from the speed and adaptability of Westinghouse induction heating.

C. P. Bernhardt
Engineering Manager,
Induction Heating Dept.

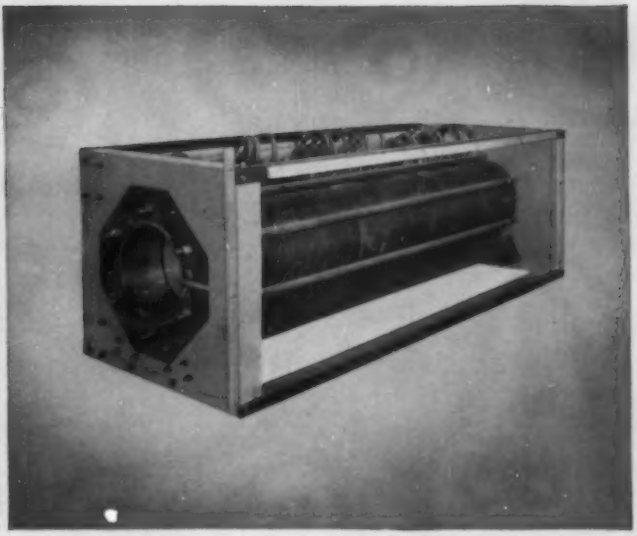
EXAMPLE: "Five thousand pounds an hour of 6-inch aluminum billets", reports Carl Bernhardt, "are heated to 1,000°F for heavy extrusion press operation." In supplying induction heating for this customer, Westinghouse saved 37% of the floor space needed for conventional furnace operation. Most important, high operating efficiency results from these five advantages in speed and flexibility:

- Short, 3-minute, start-up time. Stand-by heat losses are low.

induction heats billets on the run



2. Heating 6- or 8-inch billets to 1,000°F, this Westinghouse induction unit delivers up to 5,000 lbs of billets an hour.



3. Westinghouse coil design and engineering assures uniform heating from billet core to surface.

- Up to 80% cut in maintenance time and costs.
- Longer die life due to uniform billet heating... accurate, repetitive temperature control.
- Cooler, more productive working conditions.
- Pushbutton, automatic cycling of billet heating and handling directly to the extrusion press pickup.

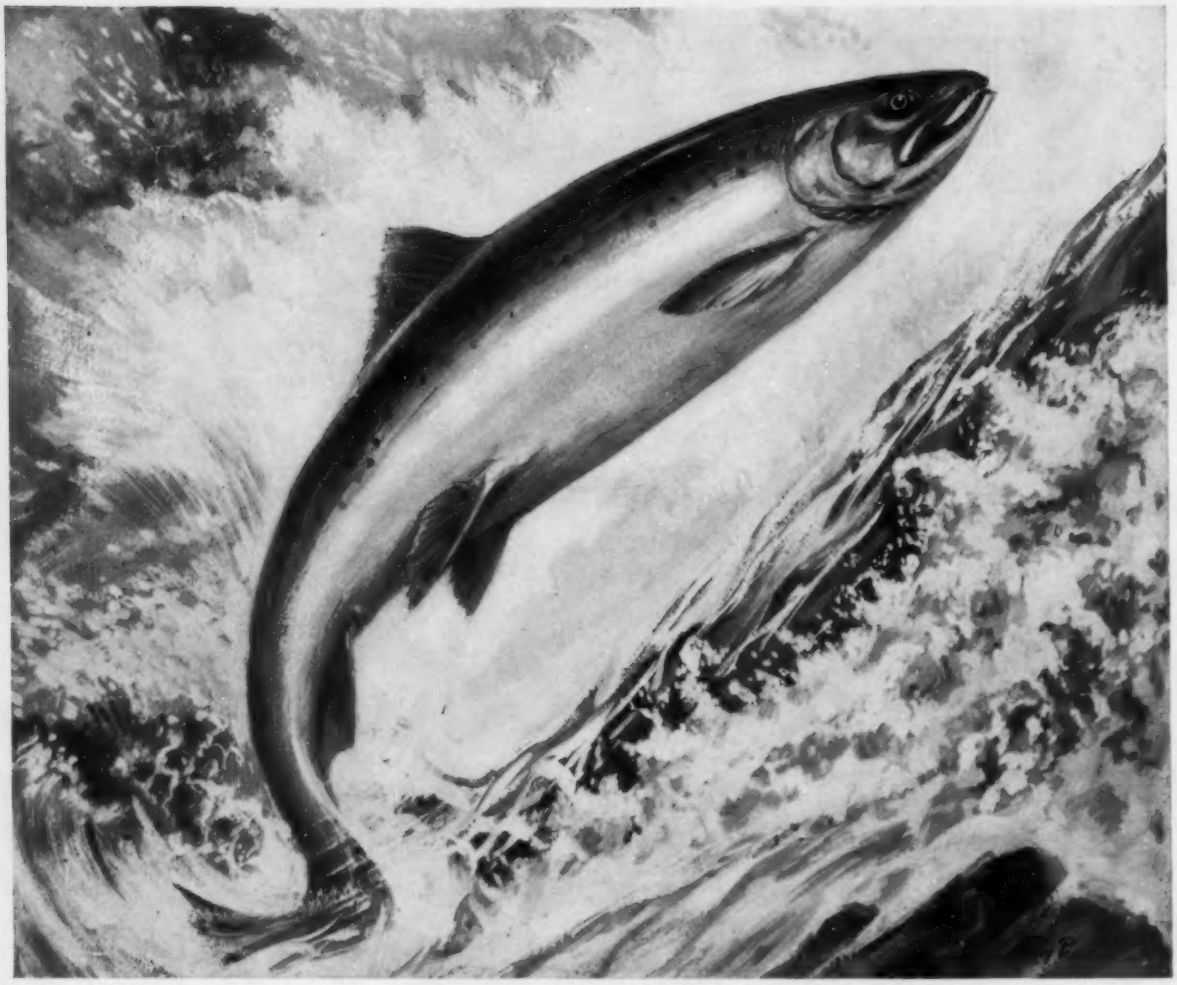
For problem solving, call on Westinghouse technical leadership in induction heating research, design and engineering. You can be sure of complete service, too, through installation field engineering and follow-up. See your local Westinghouse industrial heating sales engineer or write, Westinghouse Electric Corporation, Induction Heating Dept., 2519 Wilkens Ave., Baltimore 3, Md. J-10450

The Westinghouse Heat-Treating Family

GAS • ELECTRIC • INDUCTION

YOU CAN BE SURE... IF IT'S

Westinghouse



Upstream!

Most people watching a salmon swim upstream wonder how he does it. Seems like a lot of exertion to move from one wet spot to another. To the salmon, though, the compulsive drive upstream cannot be denied.

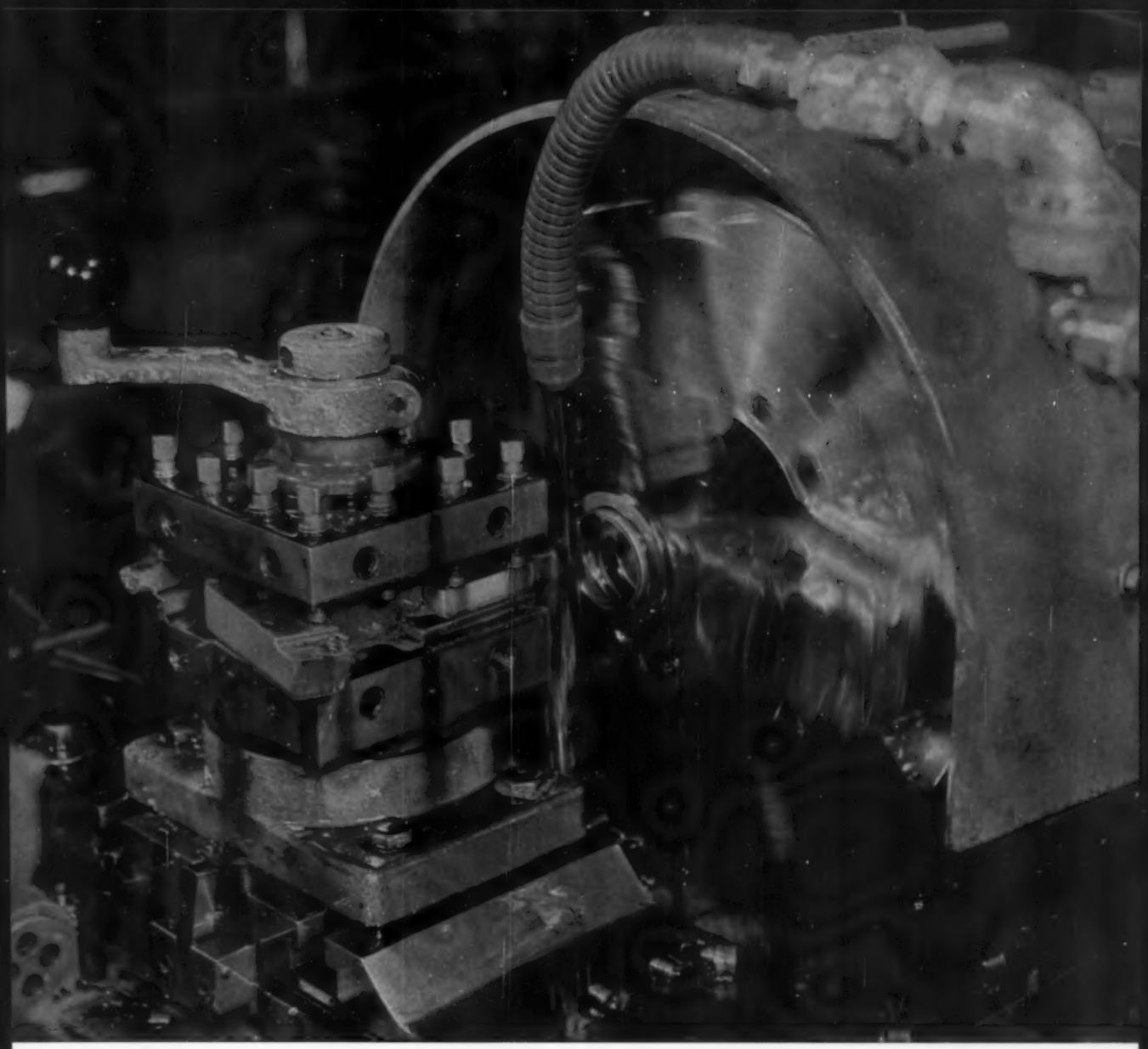
The titanium industry also has been fighting upstream these past five years. A succession of production rapids and metallurgical waterfalls have been surmounted. The dangerous hydrogen whirlpool was successfully skirted. The industry has now moved through the less white headwaters to fully competitive equality with other structural metals.

Titanium alloys of high strength, light weight and outstanding corrosion resistance are available from T.M.C.A. in all mill forms and in a full range of sizes and gages — sheet, bar, billet, extrusions, tubing and wire. Special heat-treated sheet of very close gage and flatness tolerances is in production for advanced aircraft and missiles.

Further expansions of sponge production and metal finishing facilities at T.M.C.A. are bringing titanium within reach of an ever-expanding market. Technical information and specialized engineering services are available for solving those applications having a strength, weight or corrosion challenge.

. . . FIRST IN Titanium . . . . . .

TITANIUM METALS CORPORATION OF AMERICA, 233 Broadway, New York 7, N.Y.



NOW...

a complete line of cutting oils

under one great name...

GULFCUT

GULF

GULFCUT

cutting oils increase tool life . . . lower machining costs!

- 9 different oils—a modern cutting fluid for every specific job
- Each Gulfcut oil scientifically compounded to meet exact needs

As an aid to simplification, all the famous Gulf cutting oils are now available as one complete line, under one name: GULFCUT. By ordering "Gulfcut" you can select from 9 different shop-tested cutting oils—and there's a proper type for every metal cutting need. The Gulfcut line includes mineral-lard oil, sulfurized-mineral oils, sulfurized-mineral-lard oils, sulfo-chlorinated-lard oils, and emulsifying oils. Your Gulf Sales Engineer will gladly show how Gulfcut cutting oils can mean longer tool life and reduced machining costs in your shop!

GULFCUT 11A AND 11D
Non-staining, non-corrosive mineral-lard oils, generally recommended for machining non-ferrous metals.

GULFCUT 21A, 21B AND 21C
Sulfurized-mineral oils made by a special Gulf process to provide greater sulfur activity over a wide range of machining operations. Transparent and relatively light in color.

GULFCUT 31A AND 31C
Sulfurized-mineral-lard oils that excel in performance over a wide range of machining operations on many types of steel. Have outstanding anti-weld properties and load carrying ability. Sulfur is combined in three different forms for maximum chemical activity.

GULFCUT 41A, 41B AND 41C
Sulfo-chlorinated-lard oils for high production jobs on automatic machines. Engineered with the proper combination of sulfur, chlorine and fatty oil. They also provide proper lubrication for machine tools.

GULFCUT 41TG
Sulfo-chlorinated-lard oil specifically compounded for thread grinding operations.

GULFCUT 43A
Sulfo-chlorinated oil for high production machines requiring an oil of this type for pipe cutting and threading, screw and bolt making machines, and cutting operations on steels with free and moderate machinability characteristics. Contains a corrosion inhibitor to protect ferrous metals and machine parts.

GULFCUT 43B
Specially blended sulfo-chlorinated-lard oil for high production machines requiring an oil of its viscosity and compounding. Dual purpose—suitable for machine lubrication as well as for cutting operations.

GULFCUT 45A AND 45B
High quality sulfo-chlorinated-lard oils with excellent load carrying and anti-weld characteristics to insure best results on the most difficult jobs. Have heavy concentrations of sulfur, chlorine and fatty oil. May be diluted for less difficult jobs.

GULFCUT 51A
Emulsifying oil with a wide range of uses in cutting, forming and rolling operations where a coolant with moderate lubricating properties is required. Readily mixes with warm or cold water as high as 100 to 1. Forms homogeneous and exceptionally stable emulsions.

Cutting a gear from SAE 4815 steel on Fellows Gear Shaper. Gulfcut 21-C, with relatively light color and transparency, permits close inspection of work in progress.

Machine shop at Gulf's Harmarville laboratories is a proving ground for Gulfcut cutting oils.

GULF
PETRO-ENGINEERING SERVICE

For practical technical aid, at no cost to you, call in your Gulf man. He can help you save money if you use cutting oils, lubricants, fuels, rust preventives, quenching oils, solvents, waxes or process oils. Whether you have an immediate problem—such as oil vapors, sludge or corrosion in your storage tanks, or some vital machine "running hot" —or whether you're just interested in simplifying your fuel and lubricant storage and dispensing methods . . . your Gulf Sales Engineer has a practical answer. Call him today.

[illegible]

GULF OIL CORPORATION
1822 Gulf Building, Pittsburgh 30, Pa.

Gentlemen:

☐ Please send me your free bulletin on Gulfcut Cutting Oils.
☐ Please have a Gulf Sales Engineer call on me.

Name_____

Company_____

Title_____

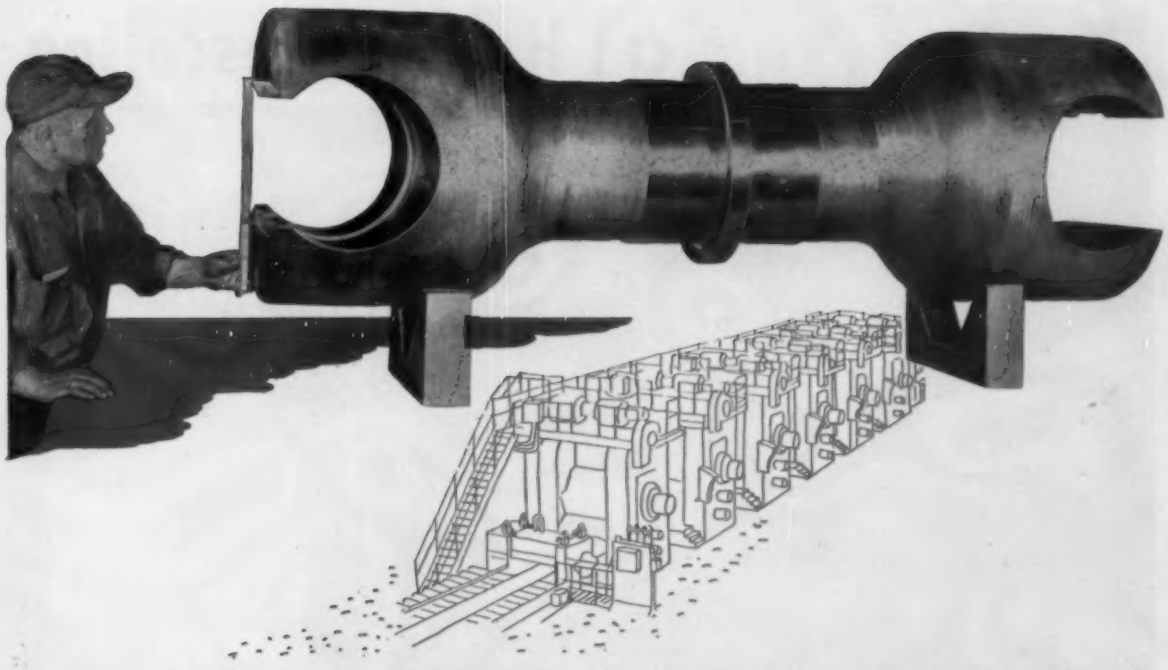
Street_____

City_____ Zone_____ State_____

GULF

GULF OIL CORPORATION
1822 Gulf Building, Pittsburgh 30, Pa.

SP-8917



SAVE MONEY with FINKL FORGINGS

Strip mills do!

They increase life and therefore reduce "down time" with Finkl finish machined spindles, once again proving that the best costs the least in the long run.

A typical example is this 98" spindle, weighing 5900 pounds, which began as a 13,000 pound forging from a 50,000 pound ingot out of our own melt shop. The utmost consideration for the spindle's end use set up the quality control program before the furnace electrodes started to arc. Then through forging, heat treating, rough and finish machining, and final inspection, each department head and his crew of craftsmen guided the program to its specified completion.

When you are considering cylinders, spindles, driveshafts, or any special purpose forging, whether rough turned or finish machined, call your local Finkl representative. He will be glad to help you plan, or call upon the more than 78 years of Finkl experience to save you money and give you the finest forgings, or die blocks, available.

• DIE BLOCKS • HOT WORK STEELS • FORGINGS • ELECTRIC FURNACE STEELS

A. Finkl & Sons Co.

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Offices in: DETROIT · CLEVELAND · PITTSBURGH · INDIANAPOLIS · HOUSTON · ALLENTOWN · ST. PAUL
COLORADO SPRINGS · SAN FRANCISCO · SEATTLE · BIRMINGHAM · KANSAS CITY
Warehouses in: CHICAGO · BOSTON · LOS ANGELES

You Get Practical Help in Descaling

DU PONT technical men bring fresh insight into your descaling operation. Their training and experience with the Sodium Hydride Descaling Process enables them to see where steps can be saved . . . to recognize conditions that may eventually lead to trouble, and to know where new developments can be applied to speed and improve descaling.

When you have a question, one of these Du Pont technicians is only a phone call away. He's equipped to analyze your process, to recommend changes where necessary. He has in back of him the finest in laboratory and technical facilities.

Best of all, there is never any obligation for this service. Du Pont's technical representatives are there to see that Du Pont chemicals are used to their maximum efficiency and that your descaling operation is the most efficient possible for your requirement. Electrochemicals Department, E. I. du Pont de Nemours & Co. (Inc.), Wilmington 98, Delaware.

DU PONT
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Better Things for Better Living . . . through Chemistry

*Technical Representative at your Call

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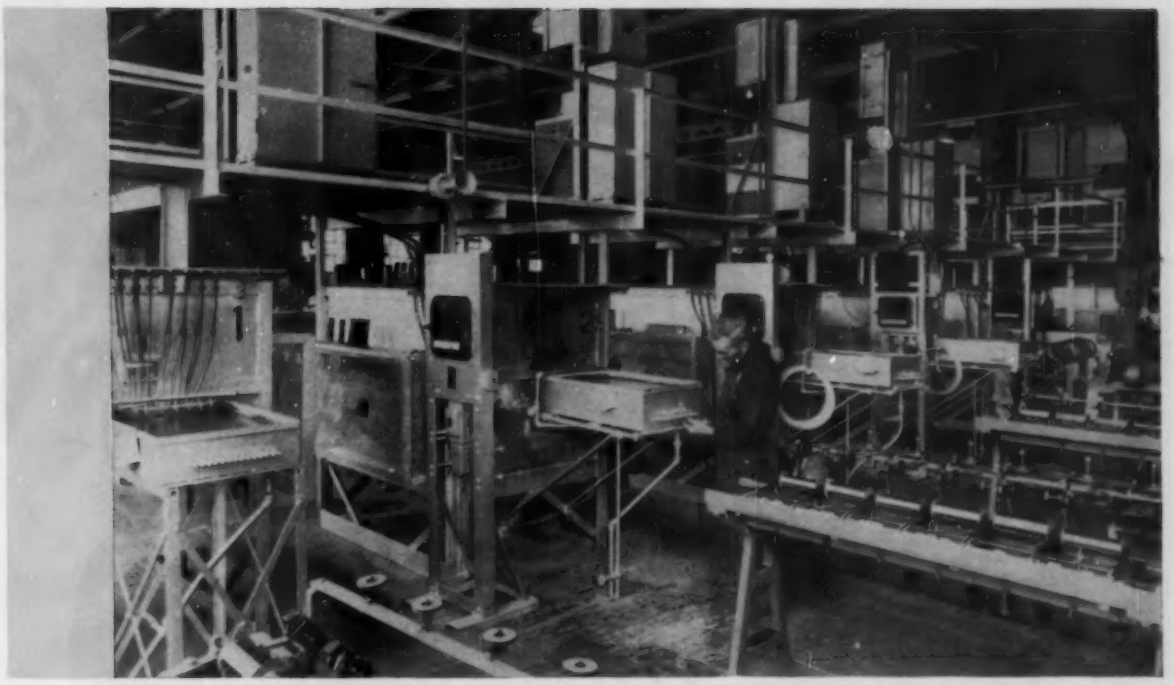
***IN CLEVELAND:**
L. W. McOmber & E. C. Friedl, *LOngacre 1-1580*

***IN DETROIT:**
D. W. Hill & J. B. Hitchcock, *UNiversity 4-1963*

***IN EL MONTE, CALIFORNIA:**
E. D. Marcum, *CUmberland 3-2761*

SODIUM HYDRIDE PROCESS FOR POSITIVE DESCALING



Now Completely Equipped With "Hot Rods." Part of a battery of nine electric strand bright annealing furnaces at the Dunkirk, N. Y., plant of Allegheny Ludlum Steel Corporation. Wire is annealed in these furnaces in alloy tubes containing a dissociated ammonia atmosphere. Operating temperature averages 2200°F. Furnaces are shut down after a five- or six-day working week.

Why Allegheny Ludlum converted to "HOT RODS"

Leading steel manufacturer reports longer life, improved performance, with CRYSTOLON heating elements*

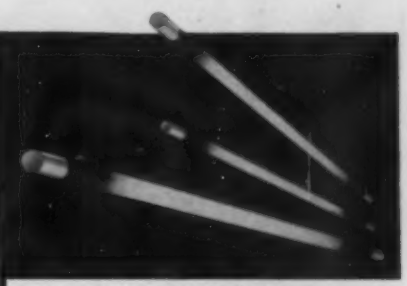
Allegheny Ludlum Steel Corporation hoped to improve the varying performance and service life of the heating elements originally installed in their electric wire-annealing furnaces.

So, they converted all nine furnaces completely to Norton "Hot Rods" — and got the improvements they wanted from the very start. For example, one set of "Hot Rods" was recently removed after 10,000 hours of trouble-free service.

Proved "Hot Rod" Advantages

Many plants report Norton CRYSTOLON heating elements outlast other non-metallic heating elements *up to 3 to 1!* This much longer life means savings in element costs, because fewer "Hot Rods" are needed. Also, you get reduced maintenance, due to less changing of elements or voltage taps. And "Hot Rods" help protect product quality because their slow, evenly matched rate of resistance increase means more uniform heating.

The big illustrated booklet, *Norton Heating Elements,* gives further facts on how "Hot Rods" can help improve your furnace operations and cut costs. For your copy write to NORTON COMPANY, Refractories Division, 321 New Bond Street, Worcester 6, Massachusetts.

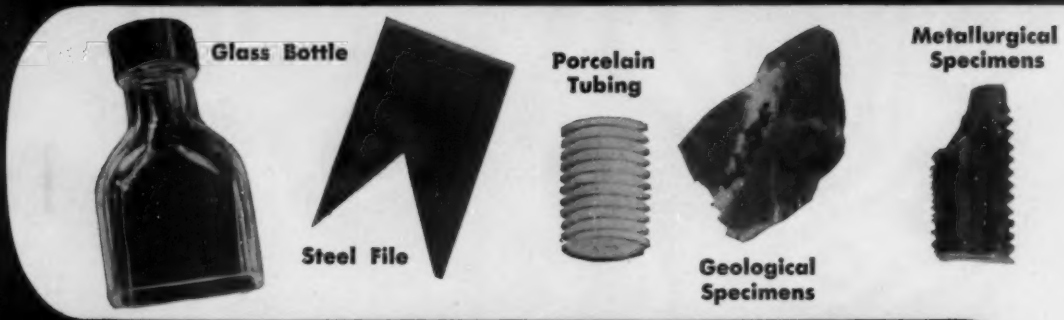


Norton CRYSTOLON Heating Elements, or "Hot Rods," are a typical Norton R_x — an expertly engineered refractory prescription for greater efficiency and economy in electric kiln and furnace operation. Made of self-bonded silicon carbide, each rod has a central hot zone and cold ends. Aluminum-sprayed tips and metal-impregnated ends minimize resistance and power loss. Available in standard sizes.

NORTON
REFRACTORIES
Engineered... R_x ...Prescribed
Making better products... to make your products better

NORTON PRODUCTS: Abrasives • Grinding Wheels • Grinding Machines • Refractories
BEHR-MANNING PRODUCTS: Coated Abrasives Sharpening Stones • Behr-cat Tapes
*Trade-Mark Reg. U. S. Pat. Off. and Foreign Countries

Intricate Cutting Operations Accomplished Quickly and Perfectly



CUTTING-OFF MACHINE

Cuts Metals, Glass, Stone, Quartz, Plastics

Exceptional for speedy and economical cutting operations in practically every type of industrial and laboratory installation. Simple to operate, this versatile machine can be used by unskilled personnel.

Special Features Include Miter Gage

MITER GAGE—Cuts of any angle can be made by a simple manipulation of this gage. Its large, convenient scale provides accurate settings.

FOOT-OPERATED ELECTRIC SWITCH — Connected to current by means of BX cable.

WATER PUMP — Fitted with individual motor drive and replaceable impeller. Pumps water from the sump to the cutting wheel.

SPRAY HEADS—Play steady stream of water on the cutting wheel to keep it cool. The water then returns to the sump.

ADJUSTABLE STOP — Used for cutting pieces to exact duplicate lengths.

Write for **BULLETIN 2237—J**

Cat. No. 5-2416, Cutting-Off Machine, 115 volt, 60 cycle, single phase, 1½ h.p. motor, size 25 x 25 x 48 in. high....**$673**

Other models available for 230 and 440 volts.

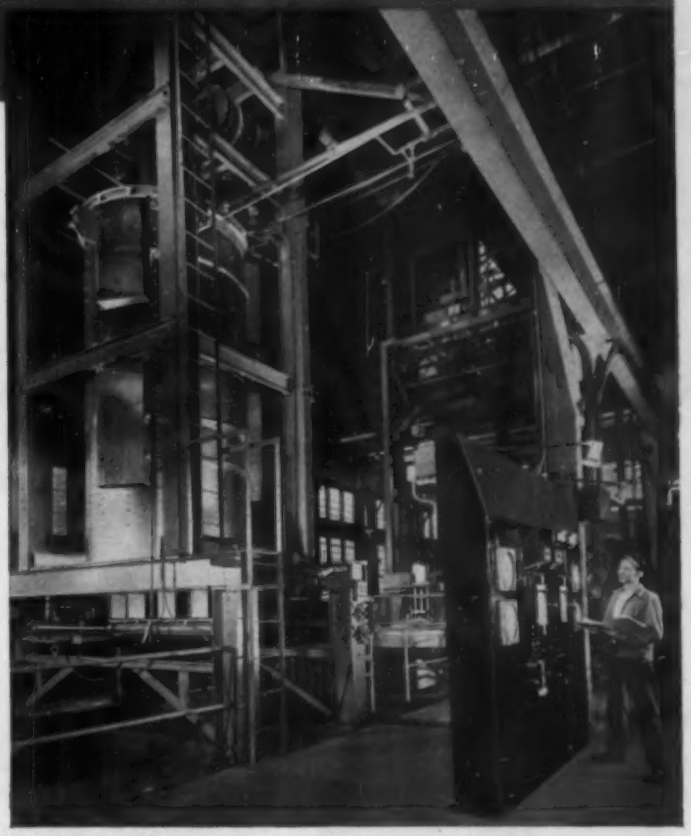
AMINCO

AMERICAN INSTRUMENT COMPANY, INC.

Silver Spring, Maryland

In Metropolitan Washington, D. C.

Another *FIRST* in Service by PITTSBURGH COMMERCIAL HEAT TREATING COMPANY



To provide additional and "special" service to industry, we recently designed and installed this vertical heat treating furnace capable of handling parts 10 feet, 8 inches long. Furnace chamber is 45 inches in diameter and maximum temperature 1850°F.

An adjacent tempering furnace of the same dimensions is also provided.

The unusual design combines a stationary furnace beneath which quench tanks (oil or water) are moved and into which heated parts are lowered.

New vertical furnace for heat treating large parts

The unit rounds out the very complete and flexible facilities we have available for all phases of heat treating.

1. ANNEALING
2. ANODIZING
3. BRAZING
4. BRIGHT HARDENING OF DIES & TOOLS
5. CARBURIZING
6. CHAPMANIZING
7. CYANIDING
8. ELECTROPLATING
9. FLAME HARDENING
10. INDUCTION HARDENING
11. NITRIDING
12. NORMALIZING
13. ROTO-BLASTING
14. STRESS RELIEVING
15. HEAT TREATING OF BAR STOCK

Write for our 32-page book entitled "Specialized Equipment and Skills".

PITTSBURGH COMMERCIAL HEAT TREATING COMPANY

49th Street and A. V. R. R., Pittsburgh 1, Pennsylvania

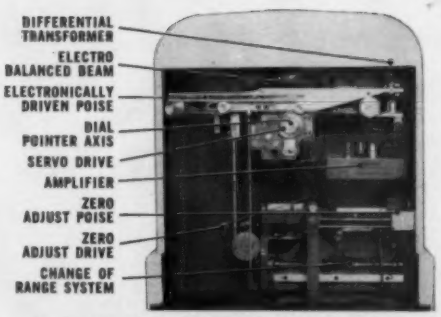
NOW... two more reasons for retiring inadequate testing machines

1. NEW SENSITIVITY
2. RAPID RESPONSE

Here are the *sensitivity* and *rapid response* plus complete instrumentation you need for testing at elevated temperatures as well as at room temperatures.

With Riehle's new Electro-Balanced Indicating Unit, you know you are actually conforming with modern, more rigid testing requirements. No longer need you go on testing superficially with inadequate machines that just weren't intended for modern test procedures.

Riehle's new sensitivity and rapid response assure you of that flexibility and precision you must now have. The new Electro-Balanced Indicating Unit is available for both hydraulic and screw power testing machines — by Riehle.



SLIGHT MOTION AT BEAM END PROVIDES SUFFICIENT SIGNAL TO OPERATE THE SERVO MOTOR . . . AND MOVE THE POISE TO ESTABLISH FORCE EQUILIBRIUM.

NEW BULLETIN . . . MAIL COUPON

Riehle TESTING MACHINES

A DIVISION OF

American Machine and Metals, Inc.

EAST MOLINE, ILLINOIS

RIEHLE TESTING MACHINES
Division of American Machine and Metals, Inc.
Dept. MP-257, East Moline, Illinois

Please send your free 4-page Bulletin RU-14-56 with full data on the new Riehle Electro-Balanced Indicating Unit.

COMPANY

ADDRESS

CITY ZONE STATE

ATTENTION MR.

APPLICATION and EQUIPMENT new products

Aluminum-Clad Copper Wire

Westinghouse Electric Co. has announced a new copper wire with a 0.0025 in. protective aluminum skin. The copper rod is first plated with a layer of silver. The silver-plated copper rod is then inserted into a thin-walled tube of aluminum. The aluminum-jacketed rod is rolled into a rod of smaller diameter and then drawn through dies into wire of the desired size and shape. The finished wire is then coated with a high-temperature insulating enamel, giving a double protected copper wire for high temperature service. Copper wire oxidizes at temperatures over 500° F., but aluminum shows no loss of size or conductivity.

For further information circle No. 295 on literature request card, page 48-B.

Vacuum Gage

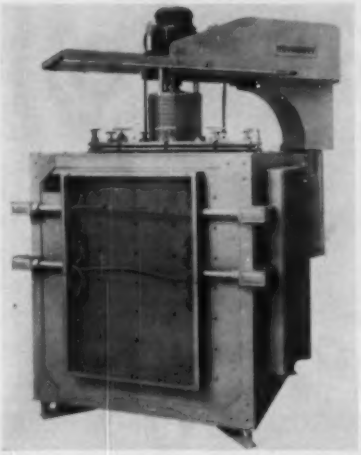
A new one-to-four station Pirani vacuum gage with a range from 1 to 2000 microns Hg has been announced by the Rochester Div. of Consolidated Electrodynamics Corp. It gives direct, continuous readings of the total

pressure of condensable vapors and permanent gases on two scales—1 to 50 microns Hg and 50 to 2000 microns Hg. A new sensing tube reduces zero drift. It operates on 115-volt power supply, but is adaptable to 230 volts.

For further information circle No. 296 on literature request card, page 48-B.

Pit Furnace

Hevi-Duty Electric Co. has announced a new pit furnace for use



with or without a protective atmosphere at temperatures to 1450° F. This furnace will perform nitriding, bright tempering, steam tempering, annealing, bluing and all low temperature non-atmosphere heat treating. The larger models feature motor operated cover lifts and the "return bend" heating elements. In the smaller furnaces, "multiple unit" elements and hand operated cover lifts are used.

For further information circle No. 297 on literature request card, page 48-B.

Core Binders

Three grades of Adcosil CO_2 core binders have been announced by Archer-Daniels-Midland Co., Foundry Products Div. One is made for ferrous metals, another for nonferrous, and the third to give greater collapsibility. All grades can be supplied with a color indicator which turns the core purple until it is properly cured, at which time it returns to its normal sand color.

For further information circle No. 298 on literature request card, page 48-B.

Zinc Phosphating

A new zinc phosphating compound for use at low temperatures in spray washing machines has been announced by Oakite Products, Inc. The new material produces a coating weighing between 150 and 300 milligrams per square foot on steel surfaces. Similar coatings are obtained on zinc. It is applied at temperatures between 120 and 140° F.

For further information circle No. 299 on literature request card, page 48-B.

Electron Diffractograph

A new model of Trueb, Taeuber electron diffractography has been announced by the New England Scientific Instruments Co. The diffractograph can be used either for direct observation of the diffraction pattern on a fluorescent screen or for photographic recording. The observation chamber has three viewing ports with a fluorescent screen 3 in. in diameter

which can be pivoted externally. It is used for research in structure of metals and especially of thin layers and surfaces.

For further information circle No. 300 on literature request card, page 48-B.

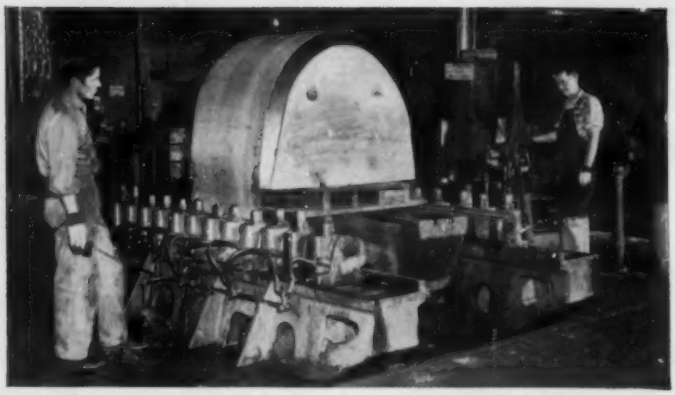
Titanium Descaling

Development of a process that descales titanium and its alloys without adversely affecting the physical and chemical properties of the metal has been announced by Turco Products, Inc. The new process requires two

Progress with **TITANIUM**

"In titanium stretch-forming, Mallory-Sharon material most consistent we have tried; simplifies fabrication"

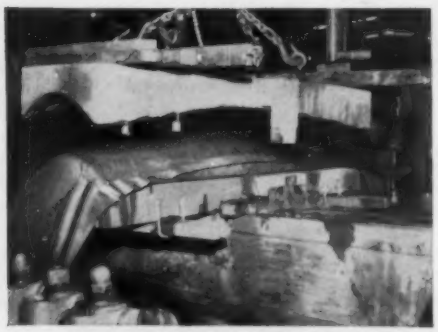
. . . reports
Hart Metal Products



1. Initial forming *of titanium sheet at Hart Metal for jet engine pod. Since Mallory-Sharon titanium is certified in a definite strength range, springback is predictable, and allowed for in dies.*

● Because of titanium's springback characteristics, uniformity is particularly important in simplifying forming. Here, Mallory-Sharon sheet is preferred material for its consistent properties, the result of strict quality control. Each heat of Mallory-Sharon commercially pure titanium is certified for average strength and limits. For dependable quality, call us for your requirements, and for technical help in application.

2. Formed sheet *is annealed to relieve stress. With sheet material in a consistent strength range, Hart Metal reports that two or three stress relieving operations are eliminated.*



3. Double contour *produced by stretch-forming. Heated dies aid in obtaining desired shape with minimum number of operations.*

4. Formed skins are *checked in fixture and given final inspection. Fabricator reports very low scrap loss with uniform strength material.*

MALLORY Ti SHARON

MALLORY-SHARON TITANIUM CORPORATION · NILES, OHIO

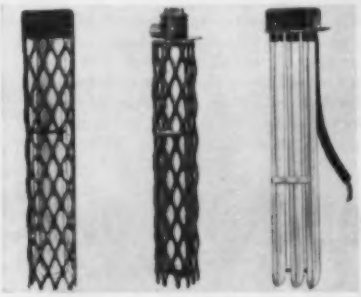
Producers of titanium and titanium alloy sheet, strip, plate, rod, bar, billets

immersion steps (one for scale conditioning and one for scale removing) and two rinsing steps, following the heat forming or heat treating operation. It requires relatively low temperatures — 270 to 280° F. as compared with 800 to 900° F.

For further information circle No. 301 on literature request card, page 48-B.

Immersion Heaters

Glo-Quartz has announced a line of immersion heaters for acid, alkaline, water, oil and hydraulic solutions. The new "U" type translucent fused quartz unit has been designed for heating electroplating and pickling



solutions. The resistance heating element is mounted within the U tube and the coil is firmly supported with a special heat-conducting powder and is sealed. Straight, multi-blade and pencil types satisfy other heating requirements.

For further information circle No. 302 on literature request card, page 48-B.

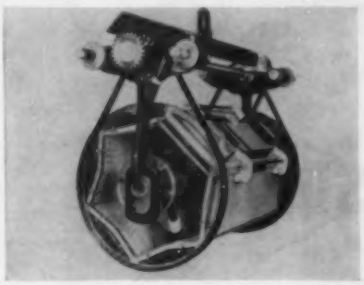
Cutting Nonferrous Plate

Air Reduction Sales Co. has announced that the Aircomatic inert gas welding process can now be used for cutting nonferrous metals. On ¼ in. plate, cutting speeds up to 132 in. per min. can be attained on aluminum, and 85 in. per minute on stainless steel.

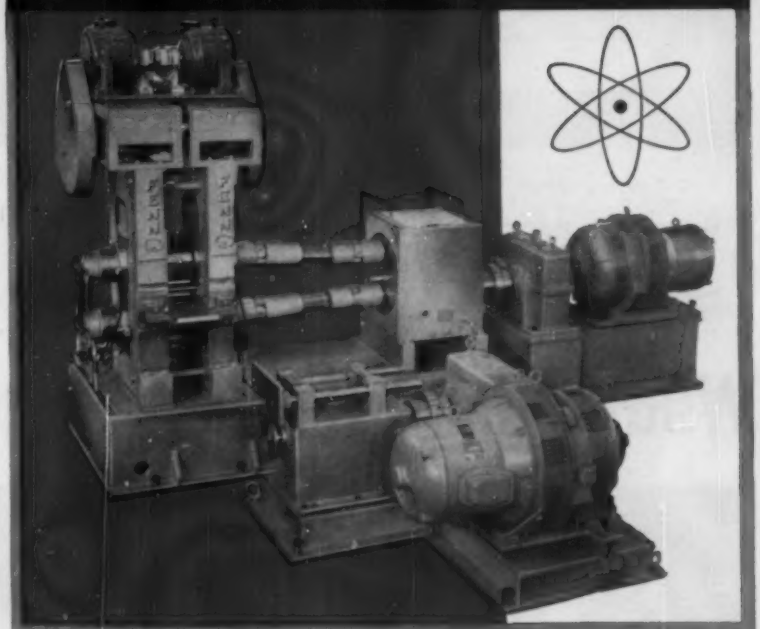
For further information circle No. 303 on literature request card, page 48-B.

Plating Barrel

A new Mercil-type barrel plating cylinder featuring a belt drive has been announced by Hanson-Van



THE MARTIN COMPANY
chooses
Fenn 4-083 Rolling Mill
for Nuclear Division



Fenn's new large combination type laboratory Rolling Mill, first shown at the Metal Show, has already been acclaimed as the finest of its size. A typical installation is in the Nuclear Division of The Martin Company at Baltimore. It is one of several important pieces of Fenn Nuclear Machinery being installed in the manufacturing division of this new plant.

The Model 4-083 (2½ x 8⅛ x 8") can be used as either a two-high or four-high mill, driving either back-up rolls or work rolls. It is capable of taking heavy reductions (up to .080" per pass) on ferrous strip at all speeds between 100 fpm and 500 fpm. Many drive combinations can be used to meet your specifications.

For complete information write for Fenn Rolling Mill catalog No. FRM-56 and list of present users of Fenn Metal Forming Equipment in the nucleonic industry.

FENN

COMPLETE MILL SPECIFICATIONS
sent upon request.
Fenn engineering service is available to help you solve your rolling problems.

Precision Rolling Mills

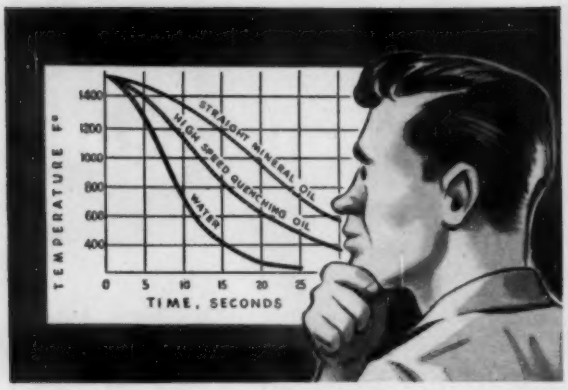
Turks Heads

Wire Shaping Mills

Swaging Machines

Wire and Tube Drawing Machines

Fenn Manufacturing Co., 509 Fenn Road, Newington, Connecticut



1. Quenching Speed. There are two basic types of quenching oils...straight mineral oils and compounded high-speed oils. If you can get the microstructure and hardness you need and have no distortion problems with a straight mineral oil, then it's the type to use. If you're not getting the results you want, increased agitation may help. If increased agitation doesn't help, or isn't practical, you should use a high-speed oil.

2. Naphthenic vs. Paraffinic. Both types of oil are used for quenching. Both have their own inherent advantages. Naphthenic oils keep oil coolers cleaner when the temperature of the oil doesn't exceed 150 F. A fully dewaxed paraffinic oil gives the most satisfactory results at temperatures over 150 F. As a rule, when all other operating factors are equal, the temperature of your oil bath tells you which type of oil to use.

What's the difference in quenching oils?

3. Thermal Stability. This is the biggest single factor influencing the useful life of a quenching oil. The higher the temperature of the oil bath, the shorter the life of any given oil. As mentioned before, at temperatures over 150 F it takes a stable, fully dewaxed paraffinic oil to give the most satisfactory results. For maximum useful life at temperatures over 200 F you will probably need a specially inhibited quenching oil.

4. Other Considerations. When quenching from a salt pot, use a straight mineral oil. Don't use an oil containing lard oil or other vegetable or animal fats. The salt carried into the oil on the parts will cause these fats to saponify and form oil-thickening grease. For bright quenching, experience shows that a straight mineral oil will give the best over-all results. For the most part, a straight oil will give cleaner parts longer.

These facts are nothing more than a guide to help you select the quenching oil best suited to your particular needs. To arrive at the final answer, there's no substitute for experience. Sun's representatives, backed up by Sun's metallurgical staff, have that experience. And, they're backed up by a *complete* line of quenching oils, paraffinic or naphthenic, regular or high-speed, straight or inhibited. Sun makes them all. For more information, see your Sun representative or write SUN OIL COMPANY, Philadelphia 3, Pa., Dpt. MP-2.

INDUSTRIAL PRODUCTS DEPARTMENT

SUN OIL COMPANY

PHILADELPHIA 3, PA. ©SUN OIL CO.

IN CANADA: SUN OIL COMPANY LIMITED, TORONTO and MONTREAL

SUNOCO

Winkle-Munning Co. The plating cylinder is driven by a standard cogged V-belt which eliminates the use of gears. The barrel is designed for total submersion during the plating process. Double flexible dangler contacts are used with the barrel, carrying current into the cylinder through both ends. Cylinder hangers are completely insulated from contacts and hanger pins.

For further information circle No. 304 on literature request card, page 48-B.

Portable Nibbler

A new pneumatic metal cutting tool has been announced by Fenway Machine Co. It cuts up to 55 in. per min. through 10-gage stainless steel without distortion on either side of

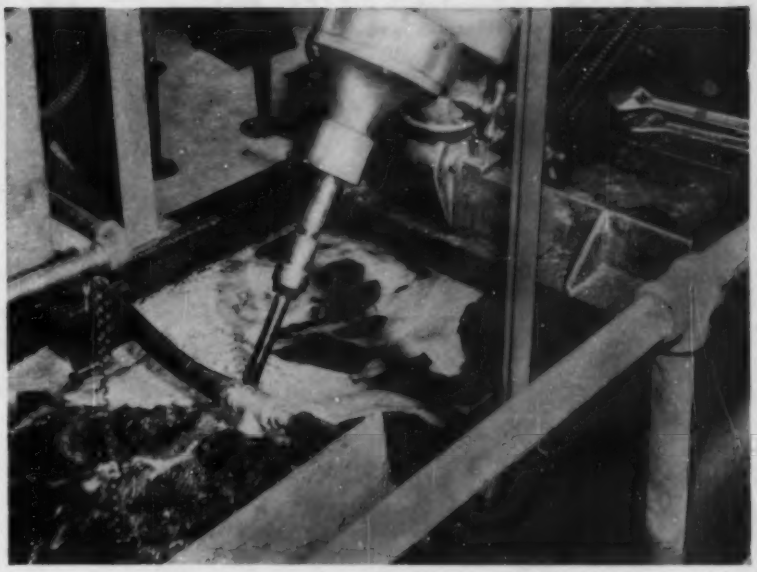
the cut. Short turning radius allows for intricate patterns and special openings to be cut in sheet metal without special devices. The nibbler weighs 13 lb. and is 13 in. long. Its frame is of cast aluminum.

For further information circle No. 305 on literature request card, page 48-B.

Low-Temperature Cabinet

A new 8-cu-ft. industrial freezer designed for testing electronic components, stabilization of metals and

thermal contraction and expansion fitting has been announced by Webber Engineering Corp. Pull-down on this unit is from ambient to −100° F. in 30 min. with a temperature range from ambient to −125° F.



Get **UNIFORM QUENCH RESULTS**
with engineered agitation

If you're considering *violent turbulence* for your quenching operations, we'd like to drop this reminder:

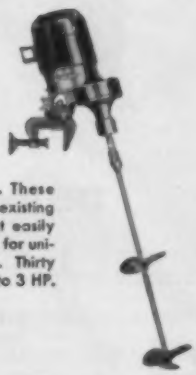
Most of the people who use violent agitation in the quench bath do it with LIGHTNIN Mixers.

And without exception, these men report good heat treating results. Greater uniformity of hardness, all over the part and from one part to the next. Greater depth of hardness, resulting in higher over-all tensile strength and toughness. No re-treats and rejects due to soft spots. No warpage or cracking. For some steels, better machinability.

You can get LIGHTNIN Mixers for any type of immersion quenching, martempering, austempering; for use with any quenchant; any size, shape, and quantity of pieces, in new or existing tanks.

For information on the number, size, type, and cost of LIGHTNINs you will need to get the results you want, just call your nearest LIGHTNIN representative (listed in Thomas' Register) or write us today.

PERMANENT . . . Often used as a component of new quench tanks and heat treating furnaces. Sizes ¼ to 3 HP.



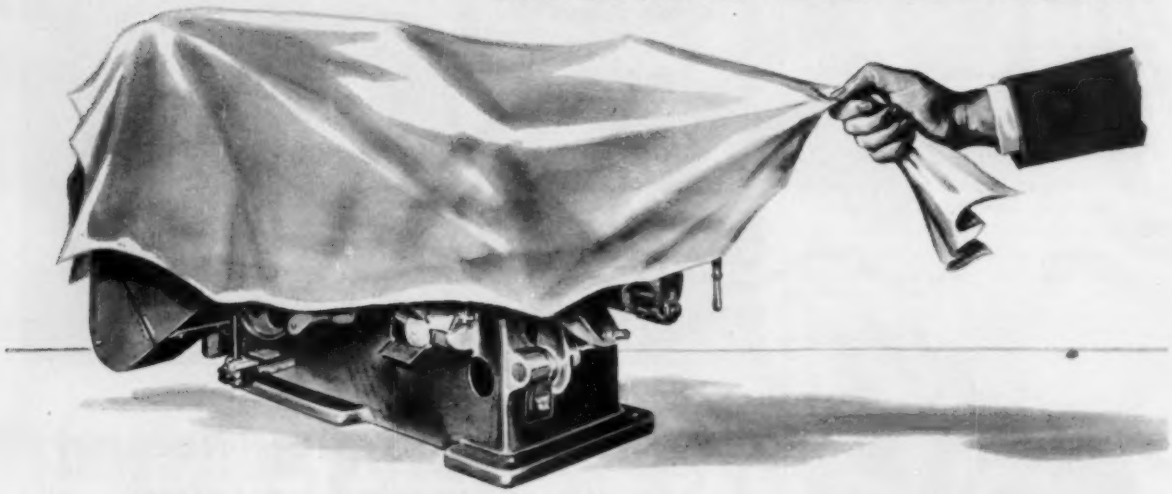
PORTABLE . . . These LIGHTNINs fit existing tanks, and adjust easily to the best angle for uniform turbulence. Thirty models; sizes ⅛ to 3 HP.

SIDE ENTERING . . . For large quench tanks; single or multiple installation. Sizes 1 to 25 HP.

"Lightnin® Mixers"

MIXING EQUIPMENT Co., Inc.
171-b Mt. Read Blvd., Rochester 11, N. Y.
In Canada: Greey Mixing Equipment, Ltd., 100 Miranda Ave., Toronto 10, Ont.

THE SECRET THE WHOLE "COLD HEADING" INDUSTRY WANTS TO KNOW!



Now a new technique—dramatic in its logical simplicity—overcomes many production problems of 'Cold Heading', results in multiple increases in production and greater die life. It is THERMAHEADING, a 'Warm Heading' method that takes advantage of the fact that ductility of metals is greatly increased in the 'Warm Zone'. This temperature range, in the case of carbon steel is 400°—700°F.

The problem of applying this heat in an efficient, mass production manner, is solved by a THERMATOOL® Induction Heating installation.

THE FEATURES OF THE THERMATOOL® SYSTEM ARE:

1. A single generator, located at any desired position, supplies high frequency power to operate as many as 5 or 6 upsetters individually of each other.

2. A heat control — continuously variable and instantly responsive — on each station permits independent temperature control.

When you see the results we believe you will say THERMATOOL® Warm Heading is a basic advance in metal forming.

THERMATOOL® "Know-How" offers you these advantages:

1. **INCREASES PRODUCTION.** Higher feed rates double, even triple, previous outputs.
2. **DIE LIFE EXTENDED.** Increased ductility means lower die pressure and fewer upsetting blows—contributing to longer die life (2-4 times) and less down time.
3. **SUPERIOR, UNIFORM PRODUCT.** Stresses and strains, which cause cracks, are lessened — which means fewer rejects.
4. **WIDENS PRODUCT RANGE.** Shapes and metals previously considered too difficult for Cold Heading can now be mass produced. 1035 steel becomes as easy to work as 1010 steel. Increases range of wire diameters handled by any given header.
5. **EASE OF OPERATION.** Designed for push-button, foolproof operation by semi-skilled labor.
6. **SIMPLE TO INSTALL.** THERMATOOL units can be quickly and easily installed on present cold heading machines.

In short, THERMATOOL Warm Heading means: lower production costs, higher profit, more satisfied customers. For further information, Write, Wire or Phone

THERMATOOL

NEW ROCHELLE TOOL CORPORATION

320 Main Street, New Rochelle, N. Y. • NE 2-5555

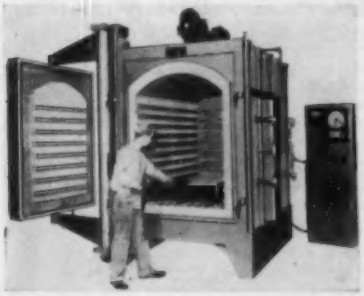
Engineering, Development, Manufacturing, Marketing of Induction, Dielectric and High Frequency Resistance Heating Equipment.

The unit operates on 440 volts, 3 phase, 60 cycles or 230 volts, single or 3 phase, 60 cycle.

For further information circle No. 306 on literature request card, page 48-B.

Furnaces

The L & L Mfg. Co. has announced a new forced convection furnace, designed for aluminum brazing, tempering, drawing, normalizing, harden-

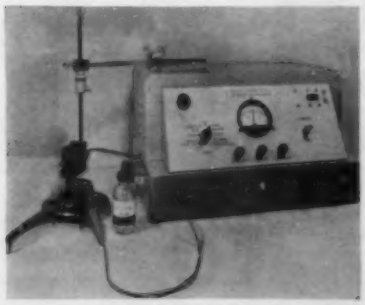


ing and other operations with and without protective and special atmospheres. The sizes vary from 13 by 13 by 25 in. to 40 by 36 by 72 in. in 15 standard models.

For further information circle No. 307 on literature request card, page 48-B.

Thickness Tester

An electronic thickness tester for determining the thickness of plating and other metallic coatings has been announced by Kocour Co. Readings are direct. A multiple position switch indicates the type of plate to be



tested. A constant pressure device automatically maintains a uniform pressure between test cell and specimen, eliminating reliance on operator judgment.

For further information circle No. 308 on literature request card, page 48-B.

Surface Temperature

A wall-mounted pyrometer with flexible arm and choice of ten thermocouple elements has been announced by Illinois Testing Laboratories. Heavy-duty welded steel case is magnetically shielded. Gasketing makes

If you're suffering from tired metals, weak metals, corroded metals—or some other costly metal ailment—it will pay you well to put in a call to a metals specialist today. May we suggest Riverside? Our metallurgists *are* specialists. And Riverside's experience in non-ferrous alloys spans more than a century. Experience, incidentally, that is yours for the asking.

For a copy of our new handbook, write to:
Riverside Metal Division, H. K. Porter Co., Inc., Riverside, N.J.

HKP RIVERSIDE METAL DIVISION
H. K. PORTER COMPANY, INC.

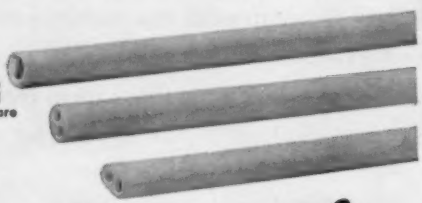
PURITY MAKES THE DIFFERENCE

Morganite Triangle RR
(Impervious Recrystallized Alumina)
Maximum operating temperature:
1950°C — 3542°F

Triangle RR is a super refractory produced particularly to meet the challenge of the ever increasing high operating temperatures in industry. Its high purity in conjunction with its impervious structure of interlocking corundum crystals makes it very resistant to chemical attack.

Triangle RR pyrometer protection tubes and insulators are highly recommended for use with platinum, platinum-rhodium thermocouples where anyone of the following considerations is important:

1. **Greater accuracy over a longer period of time**
2. **Freedom from attack of rare metals by silica or magnesia**
3. **Longer thermocouple wire life**
4. **When high rhodium content thermocouple wires are used.**



Triangle RR Furnace tubes, crucibles and other laboratory ware are described in our catalog. Send for it today.

Morganite INCORPORATED
3300 48th Avenue, Long Island City 1, New York
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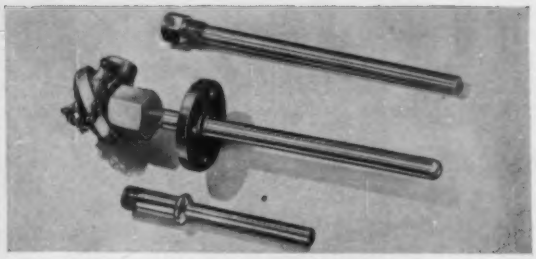
Manufacturers of Fine Carbon Graphite Products including Carbon Specialties, Motor and Generator Brushes, Carbon Piles, Current Collectors and Electrical Contacts



THERMOCOUPLE ASSEMBLIES
For *Every* Application

It's true. Among T-E's complete line of thermocouples is one for every application, every operating condition. You'll find the one for your individual need—no matter how specific. Conductor materials include Iron-Constantan, Copper-Constantan, Chromel-Alumel and Platinum-Rhodium-Platinum.

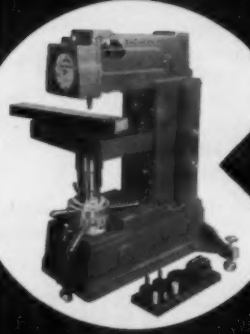
Heavy Duty Thermocouples—wire and tubular—provide the rugged construction needed for severe conditions, while retaining sensitive performance.

Protection Tubes (Thermo-Wells)—bar stock or built-up, straight or tapered, with threaded, flanged or ground-joint mountings—are available in all commercial materials for all applications.

Miniature Thermocouples are made in a wide variety of types and sizes for any installation requiring a small-size yet sensitive assembly.

Thermo Electric Co., Inc.
SADDLE BROOK, NEW JERSEY
In Canada—THERMO ELECTRIC (Canada) Ltd., Brampton, Ont.

2
Applications
(REGULAR AND SUPERFICIAL)
1
Tester



KENTRALL MODEL CT-2

Hundreds of installations over the past few years have proved the economy of the only hardness tester which combines all scales of Rockwell Test (15 to 150 kg. loads).
The Kentrall cuts costs because it does the job of two conventional testers, requires only half the space and maintenance. Write for more detailed information, plus a list of prominent users who have switched to Kentrall.

PRICE $680.

KENTRALL
THE TORSION BALANCE COMPANY
Main Office and Factory:
Clifton, New Jersey
Sales Offices:
Chicago, San Francisco

it dustproof. Over-all size is 8⅞ in. wide by 9⅛ in. high.

For further information circle No. 309 on literature request card, page 48-B.

Salt Bath Furnace

A new salt bath furnace design which permits the replacement of submerged-type electrodes without long furnace shutdowns has been announced by Ajax Electric Co. The

electrodes can be changed in an hour. They are fabricated of noncritical alloys and enter the pot from the top instead of through the back wall of the casing.

For further information circle No. 310 on literature request card, page 48-B.

Plating Equipment

A new germanium rectifier has been announced by Hanson-Van Winkle-Munning Co. Designed for small or big shop use in electroplating, anodizing and related processing, it is available in self-contained pack-

aged models with ampere ratings of 750, 1500 and 3000. Voltage range extends from 2 to 12. New features include the use of germanium junction diodes and d.c. protection system that requires no fuses.

For further information circle No. 311 on literature request card, page 48-B.

Stainless Steel

A new high-strength cast alloy with corrosion resistance and better mechanical properties than 18-8 stainless steels has been announced by the

NOTHING BUT STEEL

keeps this thundering giant on its appointed course!

Roaring out of the night at 70 miles an hour, the freight train of today is moving thousands of tons — dependent entirely upon the strength, hardness, and toughness of the steel rails to keep it on its path!

NOTHING BUT STEEL

can do the job of steel!

TRU-STEEL, the pioneer high carbon, full heat-treated steel shot has the solidity, hardness and toughness that nothing but steel has — because

TRU-STEEL SHOT is TRUE STEEL, of tool steel quality

NOW IN 50 POUND BAGS

Write for full information on TRU-STEEL and what it can do for YOU in YOUR cleaning operation!

TRU-STEEL

Manufactured by

STEEL SHOT PRODUCERS, INC.

Butler, Pa.

Subsidiary of Pittsburgh Crushed Steel Co.

Pittsburgh 1, Pa.

Sold by Pangborn Corporation, Hagerstown, Md., and by leading distributors of foundry supplies from coast to coast.

IS YOUR PLANT USING THE MOST MODERN INSPECTION TECHNIQUES?

Automatic Ultrasonic Inspection of continuously produced steel strip and welded tube is one of the most recent Reflectoscope inspection techniques brought from laboratory to production line.

Sperry Ultrasonic Reflectoscopes are found in the modern metallurgical laboratories of leaders in the metals industry. The Ultrasonic UW Reflectoscope is a new research tool that has proved its reliability and usefulness in the search for closer quality control... for new and better materials. Ultrasonic waves probe deep inside steel... nonferrous metals... ceramics... plastics–revealing even the smallest flaws and hidden internal defects. The Reflectoscope not only locates these flaws—it also determines their approximate size! In addition, it can even be used to determine elastic properties.

Does your laboratory have the latest, most efficient ultrasonic research equipment? Write today for complete information on the Sperry Ultrasonic Reflectoscope—a reliable testing method for most metals!

Regular Maintenance Inspection of production equipment, like this extrusion press, is a valuable extra duty which many owners assign to their Reflectoscope when the instrument is not required for lab and production tests.

To keep posted on latest developments in the profitable use of ultrasonic inspection, send for your free copy of our Ultrasonic Inspection News Letter. Write to:

Sperry

301 Shelter Rock Road Danbury, Connecticut

sperry products INC.

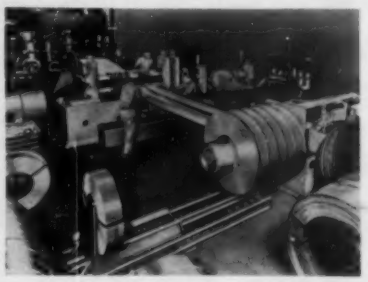
FIRST IN ULTRASONIC INSPECTION

Alloy Casting Institute. Designated as type CD-4MCu, the alloy has the following composition range: 25 to 27% Cr, 4.75 to 6.00% Ni, 0.04% C (max.), 1.75 to 2.25% Mo, 2.75 to 3.25% Cu and 1% each of silicon and manganese. Corrosion rates are of the same order as the 18-8 stainless. Elongation and reduction of area values reveal high ductility, even at hardness of approximately 300 Brinell, tensile strength of 140,000 psi. and yield strength of 100,000 psi. It has better machinability than 18-8.

For further information circle No. 312 on literature request card, page 48-B.

Uncoiler for Slitting Lines

Universal Gear and Machine Co. has announced a new payoff cone-type uncoiler reel featuring adjustable tension control, automatic or semi-



automatic lateral adjustment, from 10 to 32 in. inside coil diameter. The threading motor is reversible, and long stroke hydraulic cylinders actuate the cones.

For further information circle No. 313 on literature request card, page 48-B.

Furnace

A new furnace designed to flatten while tempering or precipitation hardening skins of aircraft wing sections in sizes up to 74 by 100 in. has been

announced by the Waltz Furnace Co. This furnace is of the circulating type and can be either gas or electric heated. The hydraulic unit is at one side and operates a hydraulic cylinder at the top of the furnace.

For further information circle No. 314 on literature request card, page 48-B.

NEW STAINLESS BAR MILL

Gives Greater Product Range

to *Rotary* Customers

Rotary's New Bar Mill

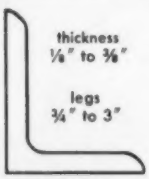
The two roughing stands have tilt tables on the delivery side with adjustable manipulators, and on the opposite side, drag chains to bring the bars into position.

Flexibility is the Keynote of Rotary's Stainless Bar Mill

Small lot production with excellent quality control, in a variety of products, can be accomplished with Rotary's new facilities.

Stainless bar and wire products are produced with specialized equipment. Rotary with its new mill can now supply a variety of products required by its stainless customers.

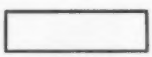
The new mill will roll the following sections:



ANGLES

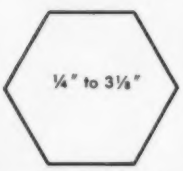
¼" to 2⅜2"

COILS

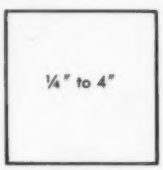


FLATS

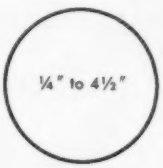
⅛" x 1¼" minimum to 1½" x 6" maximum or equivalent cross sectional area.



HEXAGONS



SQUARES



ROUNDS

Quality is maintained on this new bar mill by using batch-type furnaces for billet heating. These furnaces are of the double chamber type that permit control of the atmosphere and temperature cycles needed for the individual grades.

Batch-type furnaces with individual chamber controls permit use of the correct temperature and cycle for each grade.

Action view of repeaters on 12″ and 10″ cross country stands. Speed control is from operator's pulpit.

Rotary's New Mill is Different

- Every step of the process at Rotary—from billet heating to cutoff, cooling or coiling is completely modern.
- Quick changeover of the mill can be made whenever necessary.
- Practically all manual lifting has been eliminated by installing the latest mechanical handling equipment.
- Stainless rod is rolled continuously on the mechanized 6-stand rod mill. Intermediate bar sizes are rolled on the 10″ and 12″ mills using mechanical repeaters, whereas sections and large rounds are rolled by hand.

Rotary now has two complete bar mills. One is a completely mechanized mill for the rolling of stainless and alloy. The other, a combination mechanical and hand mill for the rolling of stainless bars, rod and sections in a wide variety of grades.

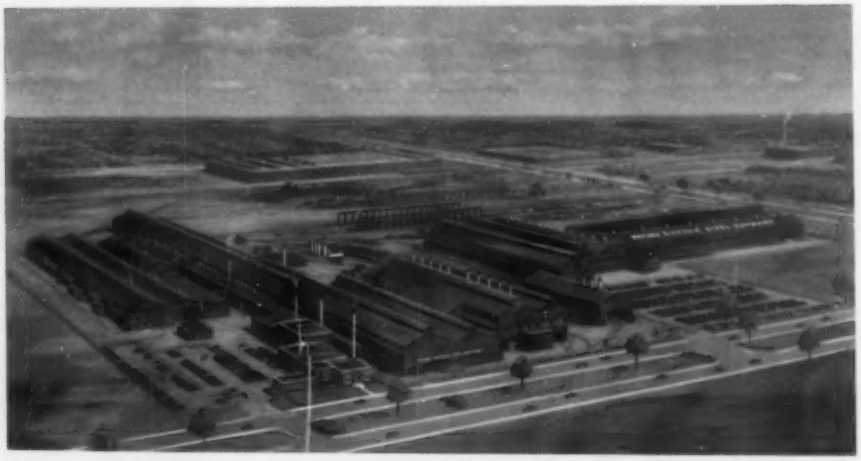
The two mills permit scheduling of orders to meet customers' delivery requirements.

Coilers to handle stainless rod from ¼″ up to and including $^{25}/_{32}$″ diameter.

Rotary's Modern Storage Facilities Insure Prompt Delivery of Quality Stainless Bars

In Rotary's Stainless Building, above, hundreds of tons of stainless steel bars are finish-ground and placed in inventory to permit the prompt servicing of inquiries and shipment of orders. The photograph below shows Rotary's modern plant. It is on 41 acres of land on the northeast boundary of Detroit.

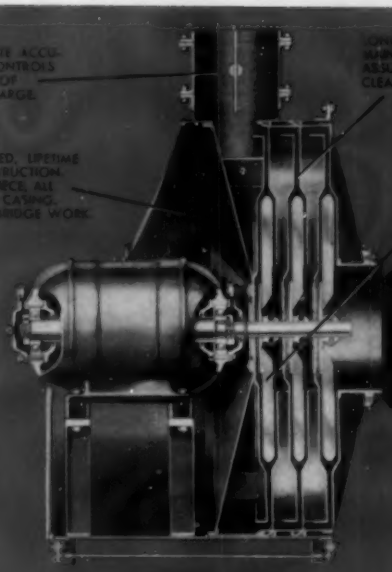
This 4-color brochure tells the complete story "How Steel is Made at Rotary." Send for your copy today.



Rotary Electric Steel Co.

Box 4606 • Detroit 34, Michigan

SALES OFFICES—Chicago, Ill. • Cleveland, Ohio • Newark, N.J.
SALES AGENTS—Indianapolis, Ind. • Fayetteville, N.Y.

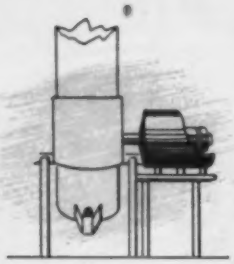

BLAST GATE ACCURATELY CONTROLS AMOUNT OF AIR DISCHARGE
LONG LIFE, MINIMUM MAINTENANCE ASSURED BY WIDE CLEARANCES
RUGGED, LIFETIME CONSTRUCTION. ONE PIECE, ALL METAL CASING. CAST BRIDGE WORK
PERFECT BALANCE OF IMPELLERS "ELIMINATES VIBRATION, INCREASES LIFE OF BEARINGS AND PACKING

FOR DELIVERY OF
HIGH VOLUME,
LOW PRESSURE AIR

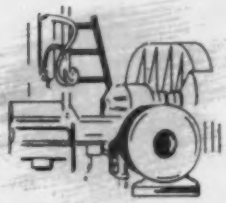
SPENCER

Turbo-Compressors are *PREFERRED*

by Equipment Manufacturers and for Replacement



CUPOLAS



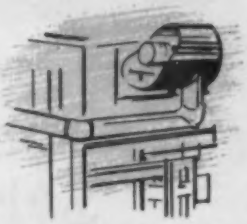
ROLLING MILLS

You'll see Spencer "blowers" . . . with the familiar "sugar-scoop" design . . . on a wide variety of equipment in foundries and metal-working plants everywhere.

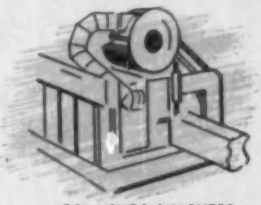
Performance is the reason. Experienced metals men know you *just can't beat* the rugged reliability, the proved-in-use performance of a Spencer Turbo.

Simple, built-to-last construction . . . mounting that requires no special foundation, no bolting down . . . discharge in any of eight positions . . . quiet operation . . . use of power proportional to amount of air used . . . these are a few of the reasons why *SPENCER is preferred.*

Capacities from ⅓ HP to 1,000 HP, up to 20,000 CFM, 4 oz. to 10 lbs. pressure.



ANNEALING FURNACES



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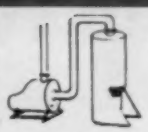
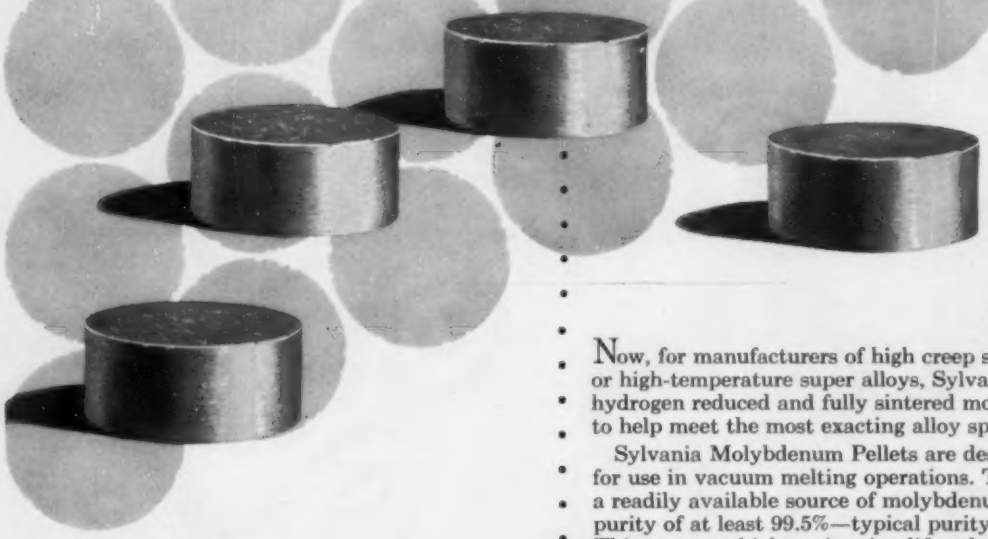


STATIONARY VACUUM SYSTEMS

PORTABLE VACUUM CLEANERS

PNEUMATIC CONVEYING SYSTEMS

To help you meet rigid production specifications . . .



Sylvania 99.5% Pure MOLYBDENUM PELLETS

for Super Nickel, Chromium, and Cobalt-base Alloys

Now, for manufacturers of high creep strength alloys or high-temperature super alloys, Sylvania offers hydrogen reduced and fully sintered molybdenum pellets to help meet the most exacting alloy specifications.

Sylvania Molybdenum Pellets are designed specifically for use in vacuum melting operations. They provide a readily available source of molybdenum having a purity of at least 99.5%—typical purity is 99.85%. This constant high purity simplifies the calculation of additions to each melt as the usual variations of purity and gas content are eliminated. By maintaining a high density, the gas content of the pellets is kept well below that acceptable for vacuum melting. In addition, the compact uniform size of the pellets (1″ in diameter by ½″ high) facilitates weighing and charging to the melt.

When you use Sylvania Molybdenum Pellets, you benefit in other ways, too. Their continuous availability means you can plan your production schedules on a long range basis. Further, their pricing stability permits you to price your own product without having to worry about fluctuating raw materials costs.

Your Sylvania sales engineer will be glad to discuss your molybdenum requirements or the high-purity tungsten available in sintered ingot form for vacuum melting. For further information, write to:

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Tungsten and Chemical Division, Towanda, Penna.
TUNGSTEN • MOLYBDENUM • CHEMICALS
PHOSPHORS • SEMICONDUCTORS

SYLVANIA

Lighting • Radio • Electronics • Television • Atomic Energy

Bob Rossi, Chief Engineer, tells
Roy Johnson, Plant Manager

"We switched to Formbrite —and saved 12 cents apiece!"

.032" gage 70-30 Formbrite is used for this 4½" diameter rearview mirror head shown full size. Strip is 5 13/32" wide supplied in heavy coils for long press runs. Copper, nickel and chromium plating on a solid brass base provides a bright, rustless, long-lasting outdoor finish.

Peerless Rearview Mirrors. "Flight-Wing," below, and the newer "Director" model, left. Housings and mounts are chromium-plated zinc-base die castings.

This easy-to-polish, superfine-grain drawing brass has been slashing finishing costs in plant after plant, on all kinds of jobs. Now Peerless Accessories Co., of Mount Holly, N. J., reports:

"To our line of lighting and safety automotive accessories, we've recently added two rearview mirror assemblies. We had been using regular drawing brass for the dished head until your representative persuaded us to try Formbrite. Here are the results, based on a very careful cost study:

Finishing procedure using regular drawing brass	Present procedure using Formbrite*
1) Grease grinding or "cutting"	Not necessary with Formbrite
2) Buffing	Light buff
3) Copper strike	Copper strike
4) Nickel plate (.00045")	Bright nickel plate (.0003")*
5) Buffing nickel	Not necessary
6) Chromium plate	Chromium plate
Cost 27¢ each	**Cost 15¢ each**

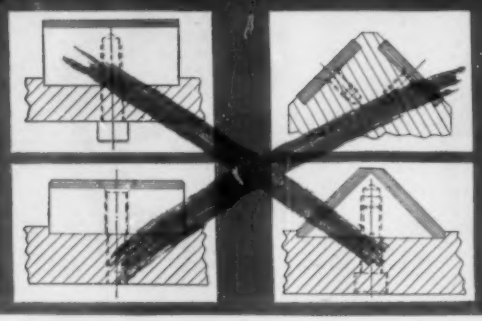
"That's a saving of 12 cents apiece. Multiply it by 3,000 to 4,000 a day and it becomes important money!"

*Formbrite's superfine grain made possible a lighter but equally serviceable plate of bright nickel

Surprisingly, Formbrite doesn't cost a penny more. Find out for yourself how its superfine grain, excellent drawing properties, strength, and scratch resistance can help you make a better product at lower cost. Write for Publication B-39. Better yet, ask us about a sample lot. The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario. 8670

Formbrite FINE-GRAIN DRAWING BRASS

an ANACONDA® product
made by The American Brass Company



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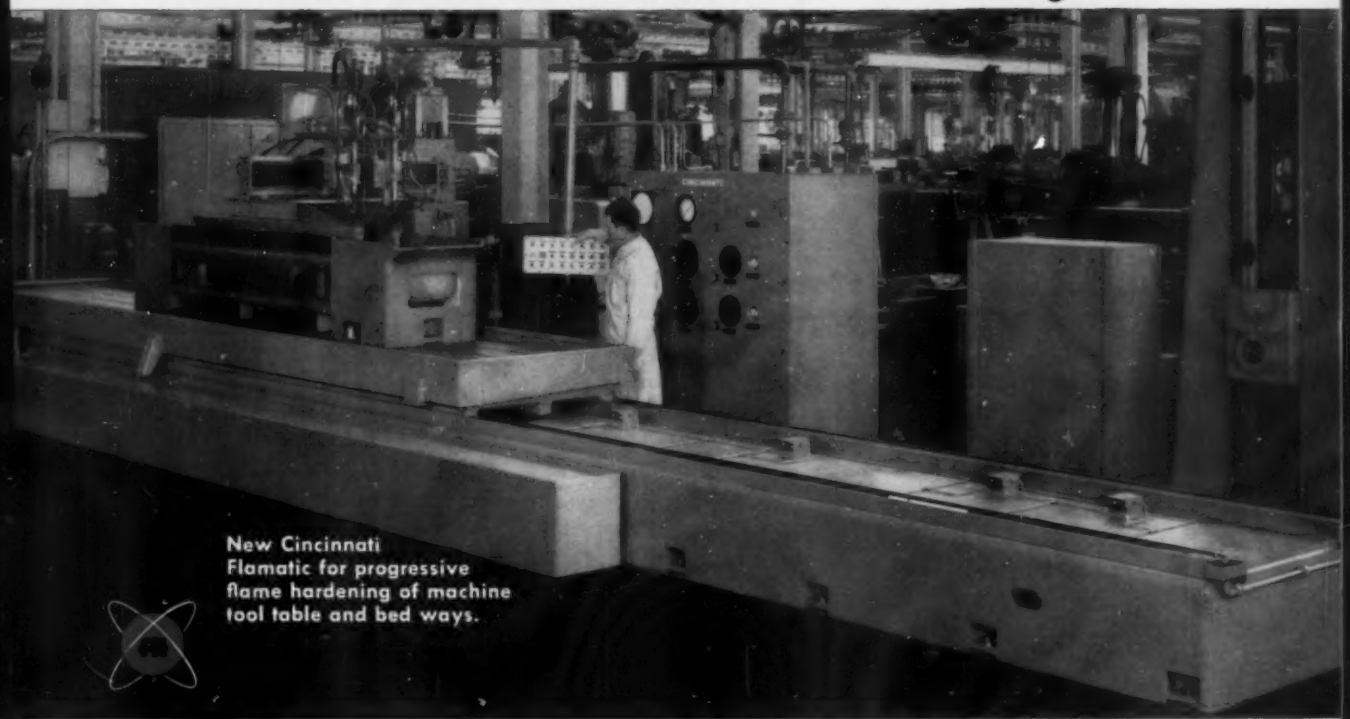
use the **flamatic** *way!*



New Cincinnati Flamatic for progressive flame hardening of machine tool table and bed ways.

Cast iron machine tool table and bed ways are now being surface hardened on this new Cincinnati Flamatic®. Uniform hardness of Shore 75-80 is achieved. This Flamatic method results in substantial cost savings over methods currently employed of fastening hardened steel wear strips or sheets to cast or welded components in sliding contact.

The reciprocating work table of the Flamatic can accommodate castings up to 20 feet long x 44 inches wide x 40 inches high, on which integrally cast ways are to be hardened. Table feed is infinitely variable between 3″ and 15″ per min., and rapid traverse is at 25 ft. per min. Flame heads are mounted on a rail, powered for rapid positioning of the flame heads to the ways to be hardened. The flame head assembly includes water spray quench and a tracer mechanism, which at all times maintains the prescribed gap distance of the flame from the way . . . compensating for any distortion of the casting.

Oxy-acetelyne fuel gas is used; however, the unit will operate on propane or natural gas. Complete operating controls are located on a pendant station. Flame hardening of work such as columns, rolls, long bars and shafts, which can be held between centers on the table, is also accomplished.

Check into Flamatic surface hardening for savings in your production processes. Call in a Process Machinery Division field engineer.

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flamatic and inductron

hardening machines

PROCESS MACHINERY DIVISION

THE CINCINNATI MILLING MACHINE CO.

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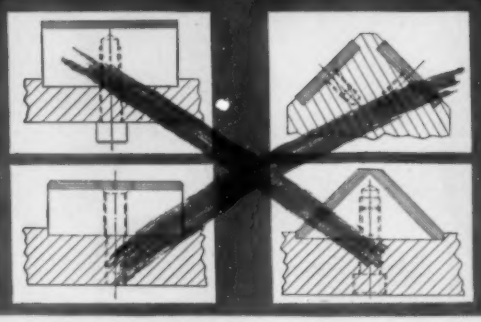

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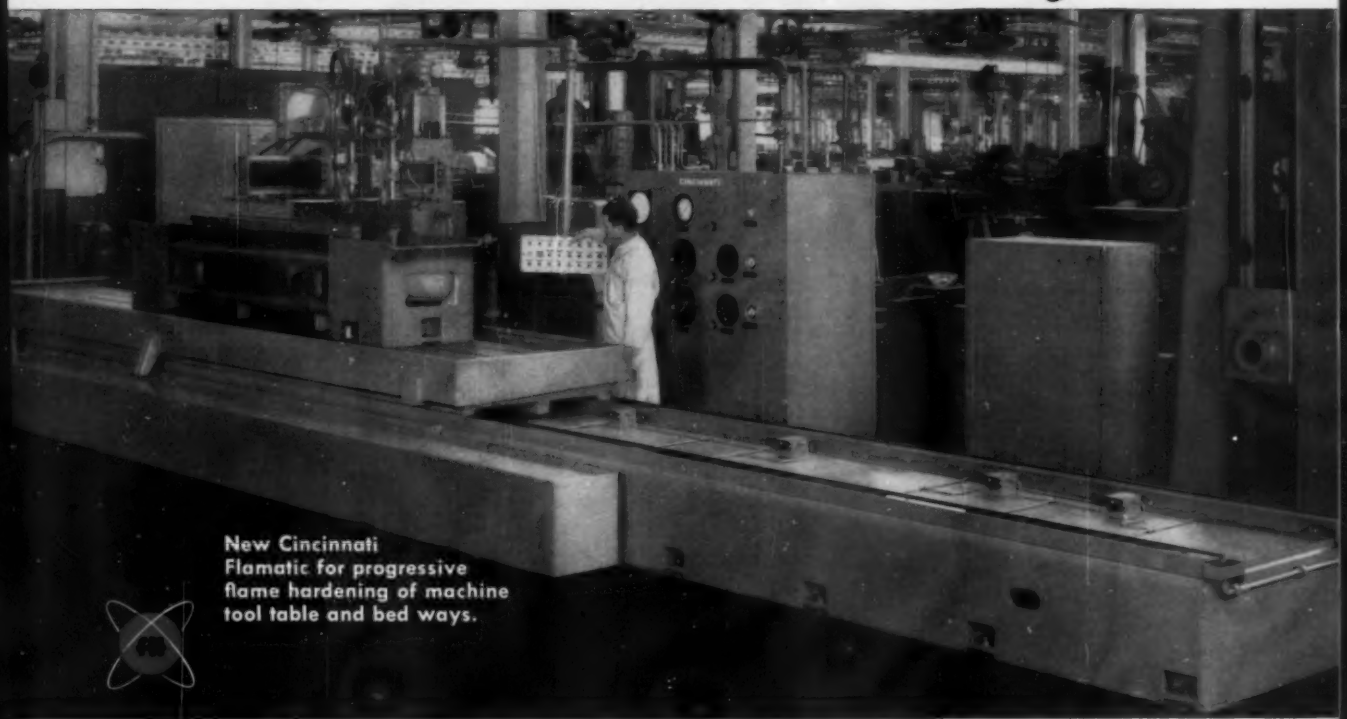

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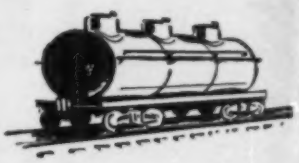

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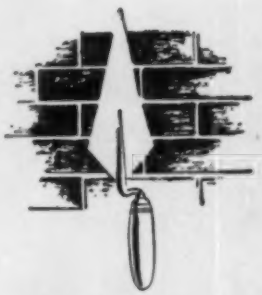

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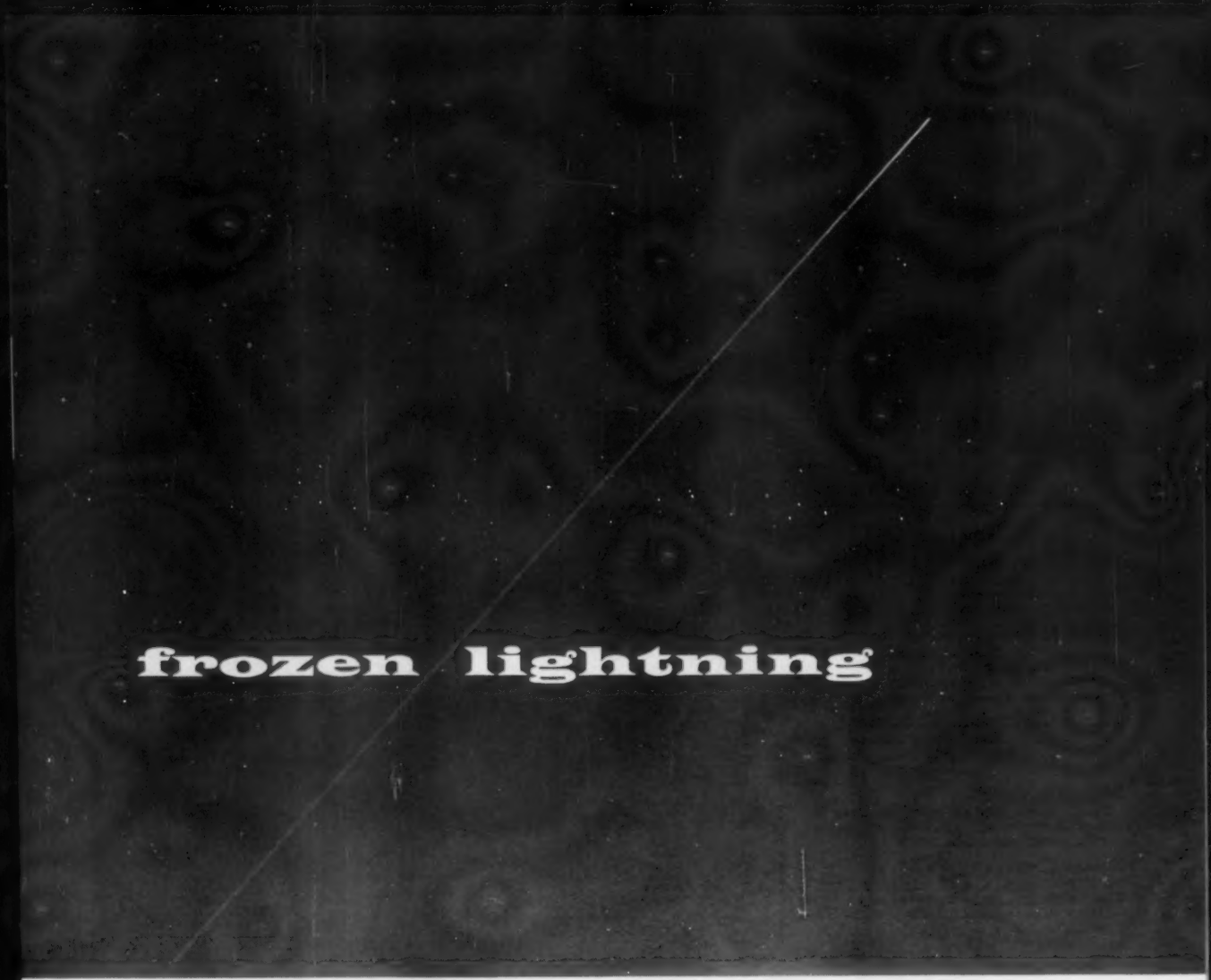
The most complete corrosion proof construction facilities available are maintained by Atlas. Shop and field fabrication, installation and follow-up service assures you of complete interest in your problems.

Write for your copy of Atlas Bulletin CC-3 containing informative data on the complete Atlas line.

ATLAS MINERAL PRODUCTS COMPANY
MERTZTOWN, PENNSYLVANIA



The Germans called the upper-atmosphere trails of their V-2 rockets "frozen lightning". When the Mach 4-5 aircraft now under development fly at 80-90,000 feet and higher, we'll be seeing frozen lightning in our own skies.

Not freezing but heating will be the real problem at these ultra high speeds. At 3000 mph, the skin and many structural components will be heated to over 1000°F, temperatures too high for alloys now used. Needed: materials strong up to 1200-1300°F for structural forgings and other stressed parts.

Engine builders, fastener manufacturers and forge shops are handling similar requirements right now, with Carpenter alloys. These alloys have gained an enviable reputation for uniform high quality, ability to meet tough specifications consistently, improved forgeability and exceptional cleanness. Forging tolerances can be tighter. Finishes are better. Rejects are far fewer.

Design properties and fabrication instructions for these alloys are summarized in our new booklet, "Carpenter Alloys for Elevated Temperature Service". For your copy drop us a line on your Company letterhead. The Carpenter Steel Company, 133 W. Bern Street, Reading, Pa.

Carpenter STEEL

Improved alloys for elevated temperature service

372. Copper Alloys
Wall chart describes 37 brass, bronze and nickel silver casting alloys. Specifications and compositions. *Henning Bros.*

373. Copper Alloys
48-page book contains tables of alloys with composition, typical uses, general, working, mechanical, electrical properties, hardness, ASTM specification numbers. *Revere*

374. Copper Alloys
60-page catalog on phosphor bronzes, nickel silvers, beryllium copper, cupronickel. Chemical and physical data. Engineering tables. *Riverside Metal*

375. Copper Alloys
40-page technical data book on eleven copper alloys. Properties, cleaning, annealing. *Seymour*

376. Cutting
Folder gives cutting performance of NewMet on 10 different steels and cast iron. Sizes and prices. *Newcomer Products, Inc.*

377. Cutting Oil
Bulletin 39 on transparent cutting oil which is designed for use on a wide variety of steels. *Sun Oil Co.*

378. Cutting Tools
36-page booklet analyzes and compares carbon, high speed, cast alloy and carbide tool materials. *Allegheny Ludlum*

379. Cutting Torch
New 4-page folder on process and torch for cutting, gouging, beveling and grooving all metals. *Arcair Co.*

380. Descaling
8-page bulletin No. 25 gives applications advantages of process, operation, maintenance and mechanics. *Hooker Electrochemical*

381. Descaling
Bulletin on system of descaling stainless, alloy steels and titanium after heat treating. *Kolene Corp.*

382. Die Casting Machines
8-page bulletin on model 600 Cleveland die casting machines of cold and hot chamber designs. Special features of machines illustrated. *Cincinnati Automatic Machine Co.*

383. Die Castings
31-page booklet on die casting with zinc base alloys. Alloy composition, Metal injection pressure, die temperature, care of dies and like subjects discussed. *Henning Bros. & Smith*

384. Die Steel
Folder and stock list on Olympic FM air hardening, high carbon-high chromium die steel with sulphide additives for improved machinability. *Latrobe*

385. Dryers
New 52-page Bulletin D-100 on dryers for air, gas and liquids for low dew points. *C. M. Kemp Mfg. Co.*

386. Electric Furnace
Bulletin 5610 on rocking electric furnace with motor-driven electrodes. Ratings, special features and characteristics. *Detroit Electric Furnace Co.*

387. Electric Furnaces
8-page Bulletin 570 on heat treating, melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Pereny*

388. Electric Furnaces
Bulletin on electric heat treating furnaces gives summary of progress in furnace developments. *Holcroft*

389. Electric Furnaces
Folder on electric furnaces with zone control, temperature indication, automatic control. *L & L Mfg. Co.*

390. Electric Furnaces
Bulletin 441 on box-type electric furnaces diagrams and describes the furnaces and lists specifications. *Hevi Duty Electric*

391. Electroplating
Bulletins on electroplated gold, rhodium, palladium, platinum, silver, nickel, and analysis of gold and gold alloy solutions. *Technic*

392. Extrusion
Folder describes the hot extrusion process and gives its history. *Jones & Laughlin*

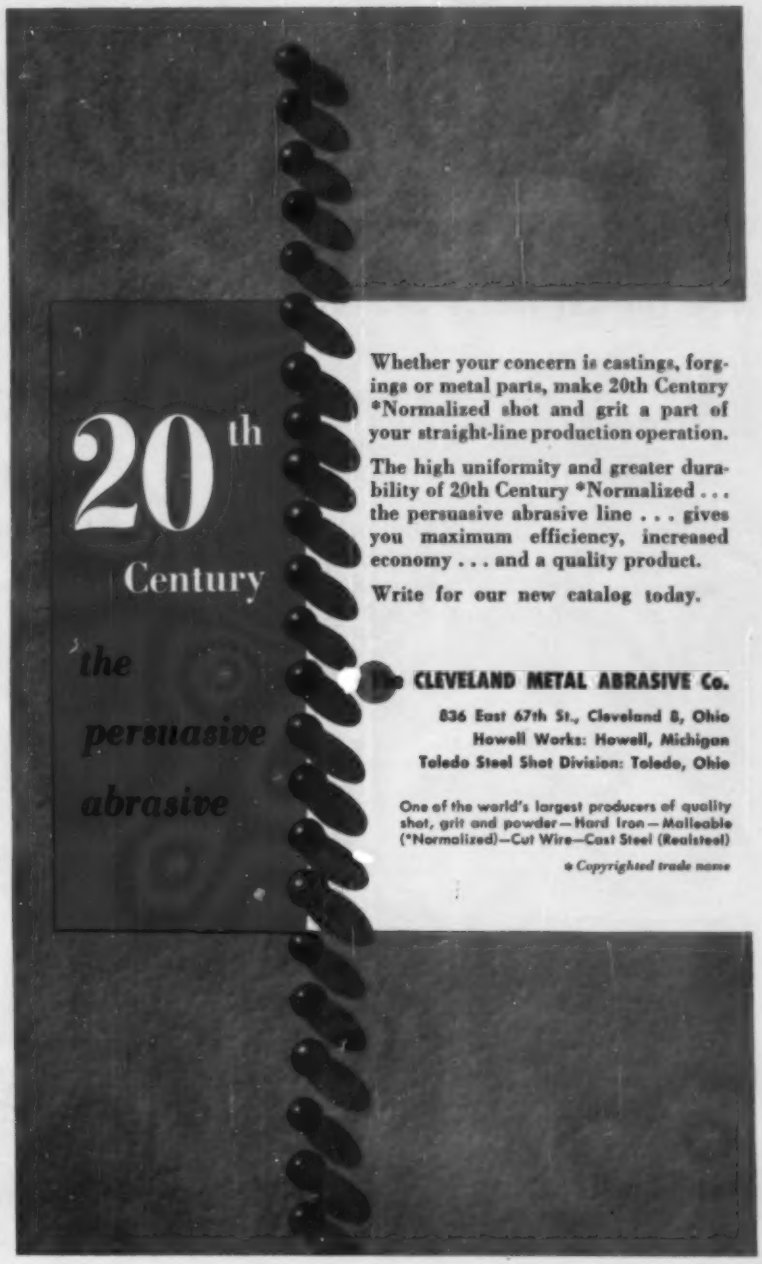
393. Fabrication
Booklet on welded steel heavy fabrication pictures and describes how various products are made. *R. C. Mahon*

394. Fatigue of Steels
Paper on effects of steel composition and heat treatment, surface finish, directionality, section size on fatigue of 1040 carbon steel, four low alloy cast steels and four low alloy wrought steels. *Steel Founders' Society*

395. Filters
4-page reprint on plating waste disposal with special emphasis on precipitation and filtration. *Filtration Engineers*

396. Finishing
New 20-page bulletin on brush finishing of metals. Brush selection charts, Brushamatic machine. *Osborn Mfg.*

397. Flame Hardening
20-page catalog on flamatic hardening machines and allied equipment. *Cincinnati Milling Machine Co.*



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Sawing Data for Four Types of Material

Type	Titanium (RC-130-B Forged)	Titanium (#140-A Forged)	Bearing Steel (AISI 52100)	Meteorite (Iron Type)
Saw Type	Demon Precision	Demon Precision	Demon Claw	Demon Precision
Saw Set	0.058 in.	0.058 in.	0.060 in.	0.058 in.
Pitch (teeth/in.)	6	6	4	6
Width	1 in.	1 in.	1 in.	1 in.
Velocity (fpm)	90	80	150	125
Lubricant	Power Cut #360	#240 Cutting Oil	#240 Cutting Oil	Power Cut #360
Machine Model	Contour-matic 26-3	Power Saw C-58	Power Saw C-58	Contour-matic 26-3
Cutting rate—Avg. (sq. in./min.)	0.50	0.88	5.00	1.25
Finish microinches (rms)	150	175	250	180-230

CUSTOMER RESEARCH LAB . . . Conducts sawing tests under shop conditions using standard DoALL Band Machines and Blades.

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398. Flow Meters
Bulletin 203 on flow meter for gas used in heat treating. *Waukee Eng'g*

399. Forgings
94-page book on die blocks and heavy-duty forgings. 20 pages of tables. *A. Finkl & Sons*

400. Forgings
16-page bulletin B-9 illustrates and tells advantages of die-pressed forgings. Copper alloys suitable for process. *American Brass*

401. Forgings
Series of articles on modern forging methods. *Hill Acme*

402. Forgings
12-page booklet on how forged weldless rings and flanges are made. Case histories. *Standard Steel Works Div., Baldwin-Lima-Hamilton*

403. Formed Shapes
26-page catalog No. 1555 contains drawings and dimensions of more than 100 shapes. *Roll Formed Products Co.*

404. Furnace Belts
42-page booklet on alloy steel belts for continuous high-temperature furnaces. Belt selection guide. *Wickwire Spencer Steel Div.*

405. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

406. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood*

407. Furnace Fixtures
Bulletin 111 on cast Ni-Cr fixtures for gas carburizing. *Fahralloy*

408. Furnaces
52-page book on gas, oil and electric pot furnaces. 16 pages of drawings of various types of furnaces. *A. F. Holden*

409. Furnaces
Folder describes complete set up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

410. Furnaces
Articles on commercial vacuum furnaces for metals and alloys and some aspects of vacuum melted metals. *National Research*

411. Furnaces
Bulletin on electric heat treating furnaces describes five series and accessories. *Lucifer Furnaces*

412. Furnaces
Bulletin No. 461 on gas, oil and electric furnaces. 17 different installations described. *Electric Furnace Co.*

413. Furnaces
Monthly bulletin on used equipment. *Metal Treating Equipment Exchange*

414. Fused Quartz
New brochure on fused quartz and silica for use in furnaces and laboratory equipment. Properties and how they are formed into usable products. *Amersil Co.*

415. Gold Plating
Folder on salts for bright gold plating. Equipment needed. *Sel-Rex*

416. Graphite
20-page brochure on significance of graphite as electrodes, anodes, molds and specialties in electrometallurgy and electro-chemistry. *Great Lakes Carbon*

417. Gray Iron Castings
8-page booklet on engineering and purchasing requirements for gray iron castings. Specific data which should be given in placing an order or asking for a quotation. *Gray Iron Founders' Society*

418. Hard Surfacing
40-page hard facing manual tells what metals can be hard faced, how to select right hard facing materials, lists step-by-step procedures and industrial applications. *Haynes Stellite*

419. Hardenable Steels
16-page reprint tells how chemical composition affects ductility and notch toughness. Triple alloy steels compared with double or single alloy steels. *International Nickel*

420. Hardness Conversion
Chart comparing various testing systems and tensile strength of carbon and alloy steels. *Babcock & Wilcox Co.*

421. Hardness Numbers
Pocket-size table of Brinell hardness numbers incorporating other tabular information. *Steel City Testing*

422. Hardness Tester
4-page bulletin on tester for both superficial and regular hardness testing. *Torsion Balance Co.*

423. Hardness Tester
Bulletin on Impressor portable hardness tester for aluminum, aluminum alloys and soft metals. *Barber-Colman*

424. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

425 Hardness Testers
20-page book on hardness testing by Rockwell method. *Clark Instrument*

426. Hardness Testers
20-page bulletin on models, applications and how to use superficial hardness testers. *Wilson Mechanical Instrument*

427. Hardness Testing
Bulletins on Wolpert-Gries machines for standard Rockwell tests. Motorized reflex type for Brinell tests. *Gries Industries*

428. Heat Exchanger
Bulletin 132 on sectional heat exchanger for use with quench bath, annealing furnace, wire drawing equipment and other industrial cooling functions. *Niagara Blower*

429. Heat Exchangers
Bulletin 105 on heat exchangers, their pressure ratings and heat transfer ratings. *Thermal Research & Engineering Corp.*

430. Heat Treating
32-page book on industrial heating, specialized equipment, skills, conversion tables and other data. *Pittsburgh Heat Treating*

431. Heat Treating Ammonia
24-page "Guide for Use of Anhydrous Ammonia" describes heat treating and other metallurgical uses. *Nitrogen Div.*

432. Heat Treating Fixtures
12-page bulletin on wire mesh baskets for heat treating and plating. *Wiretex*

433. Heat Treating Fixtures
Folder on carburizing boxes, trays, heat treat fixtures and baskets. *Misco*

434. Heat Treating Fixtures
24-page catalog B-8 on muffles, retorts, baskets, other fixtures for heat treating in gas or salt baths. *Rolock*

435. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. *Pressed Steel*

436. Heat Treating Guide
Chart guide constructed on slide rule

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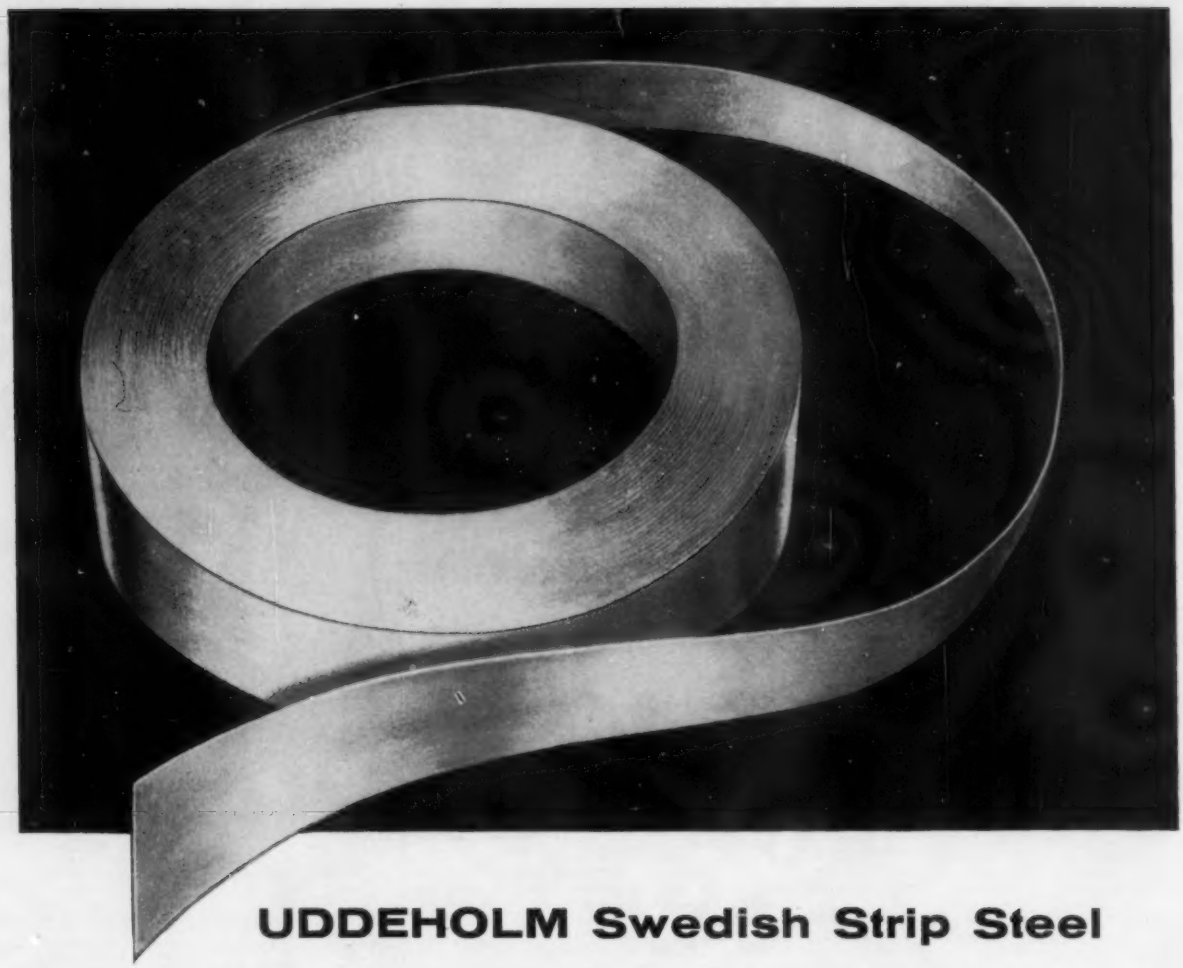

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principle for simplified hardening and drawing of tool steels. *Carpenter Steel*

437. Heaters
Bulletin on immersion heaters for electroplating solutions. *Glo-Quartz*

438. Heating Elements
24-page booklet on elements for electric furnaces and kilns includes technical data, uses, physical and electrical specifications. *Norton*

439. High-Strength Steels
48-page booklet on applications of seven nickel-copper high-strength low-alloy steels. *International Nickel Co.*

440. High-Temperature Alloy
Property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys Div.*

441. High-Temperature Alloys
28-page reprint on materials for high-temperature, high-pressure main steam piping. Bibliography. *Tempil® Corp.*

442. High-Temperature Steels
87-page book on factors affecting high-temperature properties. 45 pages of data on tensile, creep and rupture properties of 21 high-temperature steels. *U. S. Steel*

443. Indicating Unit
Bulletin RU-14-56 on electrobalanced indicating unit for testing machines. *Riehle Testing Machines*

444. Induction Brazing
Folder tells how tips of carbide may be brazed on tool shanks. *Ohio Crankshaft*

445. Induction Heating
Bulletin on low-frequency induction heating describes units for brass, copper, titanium, steel, forgings, light metal extrusion presses. *Magnethermic*

446. Induction Heating
New 36-page bulletin on high-frequency induction heating unit for brazing, hardening, soldering, annealing, melting and bombarding. *Lepel*

447. Induction Heating
12-page bulletin gives descriptions, technical data on various sizes. Water systems diagrams and standard accessory equipment. *High Frequency Heating Div., Lindberg Engineering*

448. Induction Heating
Catalog on Kilotron high frequency induction heater. *Electric Arc., Inc.*

449. Induction Heating
12-page booklet B-6519 on equipment for induction heating for forging, hardening, annealing and metal joining. *Westinghouse Electric*

450. Induction Melting
Bulletin 70 on furnace. Controls, designs. *Inductotherm Corp.*

451. Inspection
Bulletin GEA-6520 on new pinhole detector for automatically inspecting fast moving opaque strip for small holes. *General Electric Co.*

452. Inspection
New 16-page catalog on illuminated Borescopes for industrial inspection of deep recessed areas. *National Electric Instrument Co.*

453. Inspection
Descriptive information and instructions for new inspection process to detect surface flaws on all ferrous and nonferrous metals. *Zaco Laboratories*

454. Instruments
32-page bulletin 427-1 on electronic indicators, recorders and controllers, of the electrical bridge, self-balancing type. *Foxboro*

455. Insulation
New 20-page catalog on thermal insulations and refractories for application at —400° F. to +3000° F. Composition, physical and thermal properties. *Johns-Manville*

456. Insulators
Bulletin P1-55 on insulators and insulating tubing. *McDanel Refractory Porcelain*

457. Joining Stainless
24-page booklet on various welding methods, soldering, brazing, flame cutting and arc cutting of stainless. *Crucible Steel*

458. Laboratory Equipment
16-page booklet on stirrers, mixers and shakers, including air-driven, electric, magnetic stirrers, oscillating hot-plate, wrist-action shakers. *Fisher Scientific Co.*

459. Laboratory Furnace
Data sheet on laboratory vacuum melting furnace describes basic unit, vacuum chamber, vacuum pumping system. *High Vacuum Equipment Corp.*

460. Laboratory Furnaces
Data on nonmetallic resistor furnaces for research, testing or small-scale production. *Harrop Electric Furnace*

461. Low-Alloy Steel
60-page book on high-strength low-alloy steel, properties, fabrication and uses. *U. S. Steel*

462. Low-Carbon Stainless
"Melting Low-Carbon Stainless Steel" shows advantages in use of new low-carbon chromium alloy for producing extra-low-carbon grades. *Electro Metallurgical*

463. Lubricant
Literature on anti-seize molybdenum disulfide lubricant. *Bel-Ray*

464. Lubricant
8-page folder describes use of molybdenum disulfide lubricant in cold forming, cold heading and other applications. Case histories. *Alpha Molykote Corp.*

465. Lubricant
Bulletin 425 on colloidal dispersions for use in metal casting. Best formulas for achieving high lubricity and wetting action. *Acheson Colloids*

466. Machining Titanium
8-page bulletin on turning, milling, drilling, tapping, grinding. Recommendations for each. Typical properties of titanium. *Mallory-Sharon Titanium Corp.*

467. Magnesium
42-page booklet on wrought forms of magnesium. Includes 31 tables. *White Metal Rolling & Stamping*

468. Magnesium Finishing
128-page book describes all methods for finishing magnesium. *Dow Chemical*

469. Malleable Castings
Continuing series of information bulletins covering latest techniques and practices in modern malleable casting. *Malleable Founders' Society*

470. Melting Furnaces
28-page catalog on Heroult electric melting furnaces. Types, sizes, capacities, ratings. *American Bridge*

471. Melting Furnaces
48-page book 9A on line of standard furnaces from research to 200-ton steel mill types. *Pittsburgh Lectromelt*

472. Metal Identification
New booklet on Metal Monitor for nondestructive metal identification. *Brush Electronics*

473. Metal Laminates
8-page bulletin on metals used, ad-

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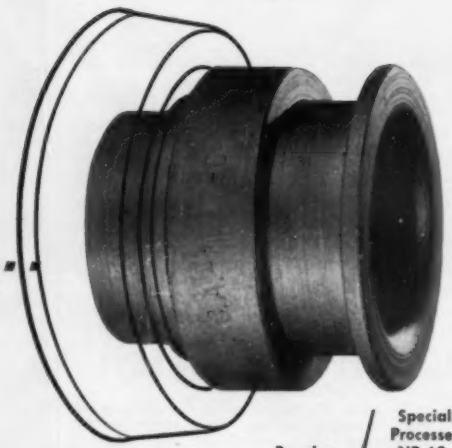

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Production per 8 hour shift (units)	675	840
Production time per 1000 units (hours) . . .	12.35	10.03
Total Labor per 1000 units (man-hours) . .	13.09	10.63

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vantages, applications, properties. *Bridgeport Brass*

474. Metallograph

20-page bulletin E-232 on Balphot metallograph with bright field, dark field, polarized light, phase contrast. *Bausch & Lomb*

475. Metallurgical Apparatus

200-page catalog of metallurgical apparatus: cutters, grinders, mounting presses, polishers, metallographs, microscopes, cameras, testing machines, analytical apparatus, spectrographs, furnaces, accessories and supplies, and 250 recommended metallurgical books. *Buehler, Ltd.*

476. Microhardness Tester

Bulletin describes the Kentron microhardness tester. *Torsion Balance Co.*

477. Microscopes

40-page catalog on metallographs, metallurgical, toolmakers, stereoscopic, polarizing, phase and other microscopes. *Unitron Instrument Div., United Scientific*

478. Moisture Measurement

12-page bulletin on how to measure water vapor in air and other gases. Gravometric, dew point and wet and dry bulb methods, and others. *Pittsburgh Lectrodryer*

479. Nickel Chromium Steels

8-page bulletin with 28 charts on composition, heat treatment, transformation characteristics and mechanical properties of the standard nickel-chromium steels. *International Nickel*

480. Nickel Tubing

New 20-page catalog gives properties and compositions of 13 analyses of nickel and nickel alloy tubing. Selection guide. *Superior Tube*

481. Nondestructive Testing

8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

482. Nondestructive Testing

Data on new nondestructive thickness tester. *Unit Process Assemblies*

483. Nonferrous Wire

Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

484. Oil Quenching

8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

485. Openhearths

12-page booklet shows how openhearths are built. Furnace binding, refractories, combustion and controls, and mechanical equipment. *Loftus Engineering*

486. Ovens

16-page bulletin No. 53 on various types of core and mold ovens, special ovens and heat treating furnaces. *Carl-Mayer*

487. Ovens

Bulletin 100 on laboratory and production ovens. Engineering, construction and control features. *Despatch Oven*

488. Pickling

80-page book, "Efficient Pickling", covers all variables of process. Many charts. *American Chemical Paint*

489. Pickling Baskets

Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

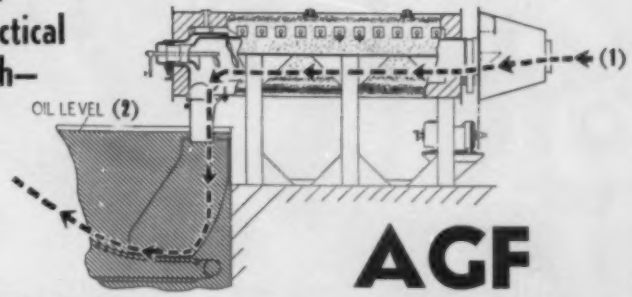
490. Pickling Baskets

12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g*

(*Continued on page 48A.*)

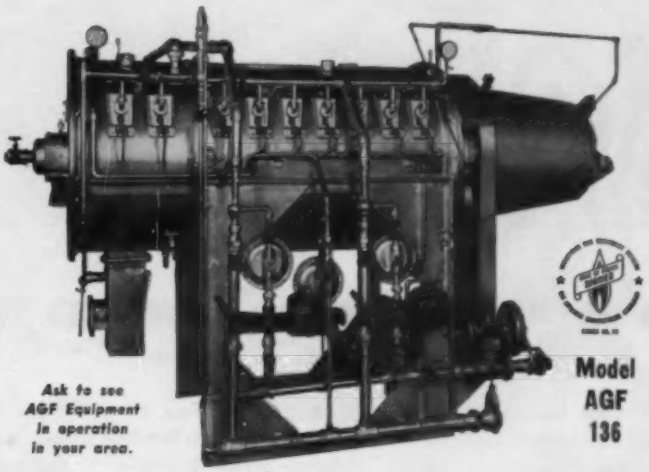
PRODUCTION LINE HEAT TREATING

is now possible and practical with—



The work is loaded at position (1) then in predetermined, exactly measured amounts, moves through the furnace and into the quench tank (2) thence out by conveyor to washing, tempering or any desired further treatment.

AGF
AUTOMATIC CONTINUOUS FURNACES



Ask to see AGF Equipment in operation in your area.

Model AGF 136

PIONEER inventors, designers and builders of industrial heat treating and gas tempering equipment since 1878.

A completely new combustion system and other engineering features permit processing ferrous and non-ferrous parts at temperatures from 600° F. to 1850° F. Clean hardening, ammonia-gas case hardening, light case carburizing of steel parts or the heat treating of aluminum parts can be accomplished with equal ease and without any modification of the furnace.

AMERICAN GAS FURNACE CO.
1002 Lafayette St., Elizabeth 4, N.J.
Please send full descriptive material upon the AGF Model 136 Automatic Furnace.

My Name is..... Title.....
Company.....
Street..... City.....
I want to heat treat..... lbs. per hr. of.....

☐ I will send samples for your recommendation.
☐ Please have your representative call at no obligation to my company.

It costs nothing to present your heat treating production problem to a qualified AGF representative in your area.

(Continued from page 47)

491. Plating
New data and specification sheet covering tin plating a wide range of nonferrous thin strip metals. *Somers Brass Co.*

492. Plating Solutions
Operating manuals for plating with metal fluoborate solutions. *Baker & Adamson.* *See page 149*

493. Potentiometer
New 64-page data sheet lists specifications and gives applications in laboratories. *Leeds & Northrup Co.*

494. Potentiometer
New bulletin No. 64 on portable pyrometer indicator. Specifications, calibrations and scales available. *Thermo Electric*

495. Potentiometer
New 8-page bulletin on portable potentiometer with interchangeable direct-reading scales. *Technique Associates*

496. Potentiometers
12-page bulletin 270 on several different potentiometers including portable models. *Rubicon*

497. Powdered Metals
New 24-page catalog 815 on 37 different models of powder metal presses. *F. J. Stokes*

498. Powdered Metals
Booklet on design, properties, production and application of brass and other nonferrous powder parts. 24 case histories. *New Jersey Zinc*

499. Pure Metals
Data sheets on vacuum melted cobalt, copper, iron and nickel. *Vacuum Metals*

500. Quenching
64-page book tells what happens when steel is heated and cooled, describes quenching media, quenching practices, interrupted quenching and cooling methods. *E. F. Houghton*

501. Quenching
16-page booklet on modified and full marquenching procedures. Hardness and dimensional control data, cooling curves, case histories. *Sinclair Refining Co.*

502. Quenching Oil
Technical bulletin on quenching oil and accelerators to provide deeper hardening. *Park Chemical*

503. Rare Earths
8-page Progress Report Number 1, "Rare Earths in Iron and Steel Melting". *Molybdenum Corp.*

504. Rare Earths
12-page handbook on rare earth chemicals, thorium. Applications of rare earths. *Heavy Minerals Co.*

505. Refractories
8-page catalog of fired refractory materials. 19 standard brands are classified and discussed as to properties and applications. *Richard C. Remmey Son Co.*

506. Refractories
8-page catalog of super refractory shapes, tubes, insulators for use to 3000° F. *Morganite*

507. Refractories
24-page booklet on how refractory grain is produced. Chemical and physical characteristics, sizes available, applications. *Norton*

508. Refractory Cement
Bulletin discusses refractories and heat-resistant concrete. *Lumnite Div.*

509. Resistance Welder
8-page bulletin 3-513 on press welder describes styles, welding heads, controls and accessories. *Taylor-Winfield Corp.*

510. Rust Preventives
12-page bulletin on water-soluble rust preventive. *Production Specialties*

511. Rust Removal
Folder on new alkaline cleaning material for removal of rust, certain types of heat scale and metallic smuts. *Oakite*

512. Salt Bath Descaling
12-page bulletin B-40 describes continuous and batch descaling lines for removing oxide from steel, bronze, copper, stainless and titanium. *Drever*

513. Sand Blasting
New 4-page bulletin 1256 on sand blasting machines for cleaning, deburring, surface preparation. *Leiman Bros.*

514. Sawing Titanium
File sheets give experiences in sawing different titanium alloys. Procedures and recommendations. *DoAll Co.*

515. Seamless Tubing
New 4-page catalog on small seamless tubing. Metal shielded wire. *Uniform Tubes, Inc.*

516. Shell Molding
New 32-page booklet on shell molding process, resins, machinery, design considerations, blowing of shell cores and shell molds. *Barrett Div.*

517. Shotblasting
16-page "Primer on the Use of Shot and Grit". Problems of blast cleaning operations. *Hickman, Williams*

518. Sintered Carbides
24-page booklet on the characteristics of the various grades, for research and design engineers. *Kennametal*

519. Sodium
40-page booklet on handling metallic sodium gives typical sodium-using processes, equipment installation, recommendations for pumping and instrumentation. *U. S. Industrial Chemicals*

520. Sodium
28-page booklet on using sodium in dispersed form tells how dispersions are prepared and handled, and their advantages. *Ethyl Corp.*

521. Spectograph
8-page booklet on optical emission, direct reading spectrographs for production control and research. *Applied Research*

522. Spectrometer
8-page Bulletin 44 on direct reading spectrometers. Operation and construction. *Baird Associates*

523. Springs
24-page Bulletin 310E on design and application of new constant-force springs. Data for high carbon and stainless steels. *Hunter Spring*

524. Stainless Castings
List of standard designations and chemical composition ranges for heat and corrosion resistant cast alloys. *Alloy Casting Institute*

525. Stainless Castings
Bulletin on advantages of corrosion-resistant castings. *Ohio Steel Foundry*

526. Stainless Steel
32-page book on corrosion resistance of stainless steels. 18 tables on tests in acid, neutral and alkaline solutions. *International Nickel*

527. Stainless Steel
20-page catalog on corrosion resistance, applications and working characteristics of 20% chromium—29% nickel stainless steels, with and without columbium. *Carpenter Steel*

528. Stainless Steel
Booklet on 430 stainless. Properties, fabrication. *Sharon Steel*

529. Stainless Steels
10-page booklet contains charts, graphs, data on cold rolled mechanical properties, elevated temperature properties, physical properties and corrosion re-

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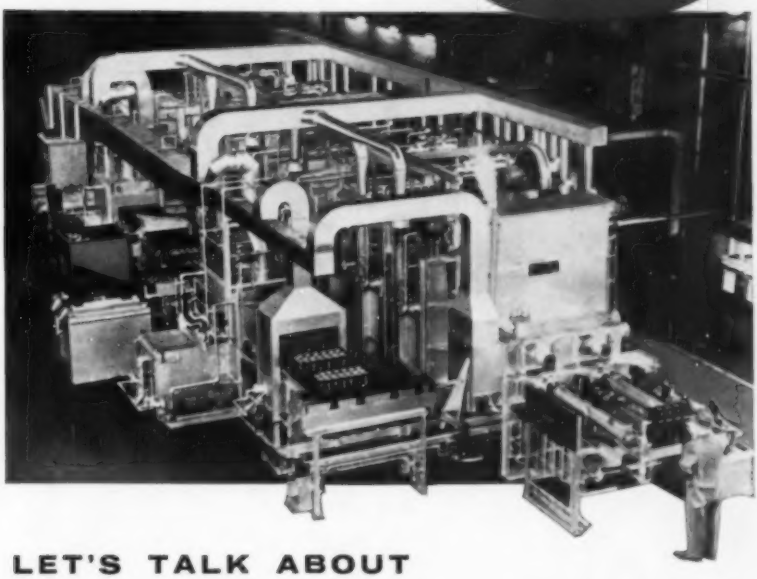
BLAZING THE HEAT TREAT TRAIL WITH **HOLCROFT**



LET'S TALK ABOUT

HEAT TREAT STANDARDS

When you take a long look at today's heat treat standards, you'll find that many of them were originated or perfected by Holcroft and Company.

For example, back in 1922 the removable electric heating element was developed. As far back as 1934, Holcroft recognized the significance and importance of equilibrium constants and their value to controlled atmosphere heat treating. And in 1945, was initiated the use of refractories and ceramics in place of scarce and expensive nickel-chrome alloys in vital parts of the furnace. These are only three of many, many innovations which have become heat treat standards in the industry.

Pioneering in the past—forward thinking for the future . . . that's what you get when you invest in a Holcroft heat treat installation. And that investment is returned in the form of higher quality control standards and lower heat treat costs. Better investigate—today!

HOLCROFT AND COMPANY

6545 EPWORTH BOULEVARD • DETROIT 10, MICHIGAN
PRODUCTION HEAT TREAT FURNACES FOR EVERY PURPOSE

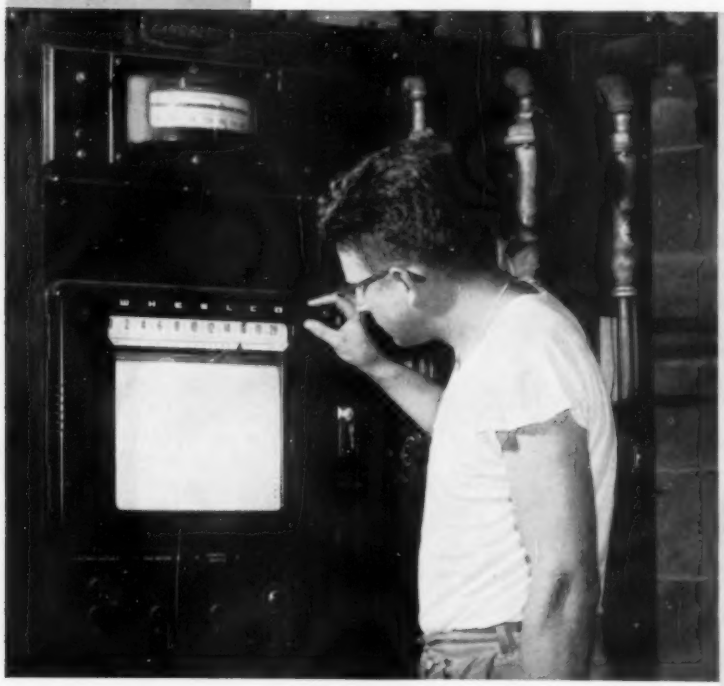
CHICAGO, ILL. • CLEVELAND, OHIO • HARTFORD, CONN. • HOUSTON, TEXAS • LOS ANGELES, CALIF. • PHILA., PA.
CANADA: Walker Metal Products, Ltd., Windsor, Ontario

THE MARK OF QUALITY

BARBER COLMAN

Wheelco Instruments

Accurate furnace control, lower costs . . . with new 8000 series POTENTIOMETER-RECORDER



Accurate temperature control is insured, operating costs and problems reduced by the new Wheelco 8000 Series Potentiometer-Recorder. Here you see it applied in the control panel of a Lindberg Carbon Nitrider operating at a large Midwestern heat-treating plant. Among other functions, in this application the 8000 Series Recorder actuates a Barber-Colman Class 2 HYCC power unit operating a North American combination air-gas valve. The furnace is a radiant-tube type, capacity 500 lb per hour. Instrument at top of panel is a Wheelco Panelmount Limitrol.

Call your Wheelco field engineer for Bulletin F-7747 — learn how the new 8000 Series Potentiometer can improve your operation:

FUNCTIONS Indication • Control • Recording

VARIABLES Temperature • Pressure • Speed • Strain • Hydrogen Ion (pH)

FEATURES Maximum accuracy • Simplified operation • Minimum maintenance • Plug-in components • Standard electronic tubes • Wide selection of scale ranges

BARBER-COLMAN COMPANY

DEPT. N, 1518 ROCK STREET, ROCKFORD, ILLINOIS

BARBER-COLMAN of CANADA, Ltd., Dept. N, Toronto and Montreal, Canada

sistance of chromium-nickel-manganese steels. *Allegheny Ludlum*

530. Stainless Strip

32-page brochure on 20 types of stainless strip steel. Recommended applications, chemical, physical and mechanical properties, corrosion resistance. *Superior Steel Corp.*

531. Stainless Tubing

8-page folder TB-410 on use of seamless and welded stainless steel pipe and stainless steel welding fittings for corrosive environments and elevated temperature applicants. *Babcock & Wilcox*

532. Stainless Tubing

New 12-page brochure on stainless steel heat exchanger and condenser tubes. Process of manufacture, chemical composition and analysis. *Republic Steel*

533. Stainless Wire

32-page aid to selection of proper stainless steel wire for particular application discusses austenitic, ferritic and martensitic grades. *Crucible Steel*

534. Steel

Bulletin on Yoloy "S" steel. Properties, welding, chemical analysis, corrosion resistance, strength. *Youngstown Sheet and Tube Co.*

535. Steel 52100

Stock list on 52100 tubing, bars and ring forgings. *Peterson Steels*

536. Steel Castings

Two bulletins on medium and medium high carbon steel casting specifications. Allied specifications, analysis, properties, hardenability. *Unitcast*

537. Steelmaking

Beautifully illustrated brochure on steelmaking, annealing, hot rolling, finishing. *Rotary Electric Steel*

538. Strain Gages

8-page article on performance of SR-4 high temperature strain gages and how to apply them in "Testing Topics". *Baldwin-Lima-Hamilton*

539. Swaging Machines

16-page catalog on complete line of swaging equipment contains data on rotary swaging process and its applications. *Fenn Mfg. Co.*

540. Tempilstiks

"Basic Guide to Ferrous Metallurgy", a plastic laminated wall chart in color. *Claud S. Gordon*

541. Test Specimens

Data on machine for cutting test specimens to ASTM specifications. *Sieburg*

542. Thermocouple Data

New bulletin F-5228-3 on construction and application of thermocouples and radiation detectors to industrial control. How to check, make, select and size thermocouples. *Wheelco*

543. Thermocouples

32-page file book on pyrometer accessories. Selection of thermocouple and protective tube. *West Instrument Corp.*

544. Thickness Gage

Folder on pocket-size gage. How to use it. *Ferro Corp.*

545. Thickness Testing

10-page bulletin 2253 on coating thickness gages. Standard and special purpose gages. Data on how to measure coatings. *American Instrument Co.*

546. Tin News

Interesting monthly report covers important current developments in the production, marketing and use of tin. *Malayan Tin Bureau*

547. Titanium

Literature on chemical processing. Processes for removing and preventing heat treat scale on titanium. *Turco Products*

548. Tool and Die Steels

26-page book on six oil and air hardening steels for high-production tools and dies. Many uses illustrated. *Bethlehem*

549. Tool Steel

44-page stock list is indexed and includes sizes, weights, and analyses. Decimal conversion and hardness conversion tables. *Uddeholm*

550. Tool Steel Selector

Twist the dial of the 9-in. circular selector and read off the tool steel for your application. *Crucible Steel*

551. Tube Welding

Bulletin on high-frequency tube welding equipment. Applications, materials which may be welded by this process. *New Rochelle Tool*

552. Tubing

8-page catalog on carbon and alloy steel tubing of mechanical, pressure, airframe and aircraft mechanical quality. *Ohio Seamless Tube*

553. Tubing

New 64-page handbook on use of tube mills in manufacture of pipe and tube. Step-by-step description of the electric-weld process. *Yoder Co.*

554. Tungsten

20-page bulletin on manufacture, properties and uses of tungsten. Flow chart of tungsten production. *Sylvania Electric Products*

555. Ultrasonic Cleaning

Folder on Sonogen ultrasonic generator for metal cleaning. *Branson*

556. Ultrasonic Generators

Data sheet on operating principles and specifications for high-power ultrasonic generators. *Acoustica Associates*

557. Ultrasonic Inspection

Ultrasonic Inspection Newsletter, No. 2, contains article on immersion inspection of wing spars for jet fighters. *Sperry*

558. Ultrasonic Testing

Data folder describes instruments using ultrasonics for various tests—immerscope, "B" scan and flaw recorder. *Curtiss-Wright*

559. Vacuum Metals

21-page report on vacuum melted metals discusses equipment, properties of metals, applications. *Ajax Electrothermic*

560. Vanadium Tool Steels

12-page booklet gives properties, heat treatment, effect of tempering, hardenability of chromium-vanadium tool steels. *Vanadium-Alloys Steel*

561. Welding Electrodes

84-page pocket-size booklet describes characteristics, coating, sizes of various electrodes. *Harnischfeger*

562. Welding Equipment

Catalog on Cadweld process and arc-welding accessories. *Erico Products*

563. Welded Tubing

12-page booklet on electric-resistance welded steel tubing. Size and gage range charts for square-welded, hot and cold rolled and rectangular-welded, hot and cold rolled tubing. *Revere*

564. Welded Magnesium

Various welding processes for magnesium, stress relief and recommended procedures. *Brooks & Perkins*

565. X-Ray

12-page bulletin on gamma radiography tells how to select the source, equipment, techniques and fundamentals of gamma radiation. *Picker X-Ray*

566. X-Ray Microscope

New catalog includes micrographs, theory of operation and technical details. *General Electric, X-Ray Dept.*

567. Zirconium

New 18-page pocket-sized book on manufacture, properties, metallography, machining, metal powders. Extensive bibliography. *Titanium Alloy Mfg. Div.*

FEBRUARY, 1957

295	320	345	370	395	420	445	470	495	520	545
296	321	346	371	396	421	446	471	496	521	546
297	322	347	372	397	422	447	472	497	522	547
298	323	348	373	398	423	448	473	498	523	548
299	324	349	374	399	424	449	474	499	524	549
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301	326	351	376	401	426	451	476	501	526	551
302	327	352	377	402	427	452	477	502	527	552
303	328	353	378	403	428	453	478	503	528	553
304	329	354	379	404	429	454	479	504	529	554
305	330	355	380	405	430	455	480	505	530	555
306	331	356	381	406	431	456	481	506	531	556
307	332	357	382	407	432	457	482	507	532	557
308	333	358	383	408	433	458	483	508	533	558
309	334	359	384	409	434	459	484	509	534	559
310	335	360	385	410	435	460	485	510	535	560
311	336	361	386	411	436	461	486	511	536	561
312	337	362	387	412	437	462	487	512	537	562
313	338	363	388	413	438	463	488	513	538	563
314	339	364	389	414	439	464	489	514	539	564
315	340	365	390	415	440	465	490	515	540	565
316	341	366	391	416	441	466	491	516	541	566
317	342	367	392	417	442	467	492	517	542	567
318	343	368	393	418	443	468	493	518	543	
319	344	369	394	419	444	469	494	519	544	

METAL PROGRESS,

7301 Euclid Avenue, Cleveland 3, Ohio

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Title _____

Company _____

Address _____

City and State _____

Postcard must be mailed prior to May 1, 1957.
Students should write direct to manufacturers.

A REFRIGERATOR, TOO, CAN BE THE STRONG, SILENT TYPE

One home refrigerator with a reputation for silence and long service life depends upon B&W for "the type of tubing necessary to the efficient operation of the refrigerator. Without it, the refrigerator could not provide the required performance. It must last the life of the unit."

To meet that tough specification for evaporator coils and high temperature coils, B&W supplies Electric-Resistance-Welded Tubing with precision-made serrations on the I.D. Rockwell hardness must be held within close tolerances, and the seam-weld must withstand 1,000 pounds pressure—no interior surface copper is permitted.

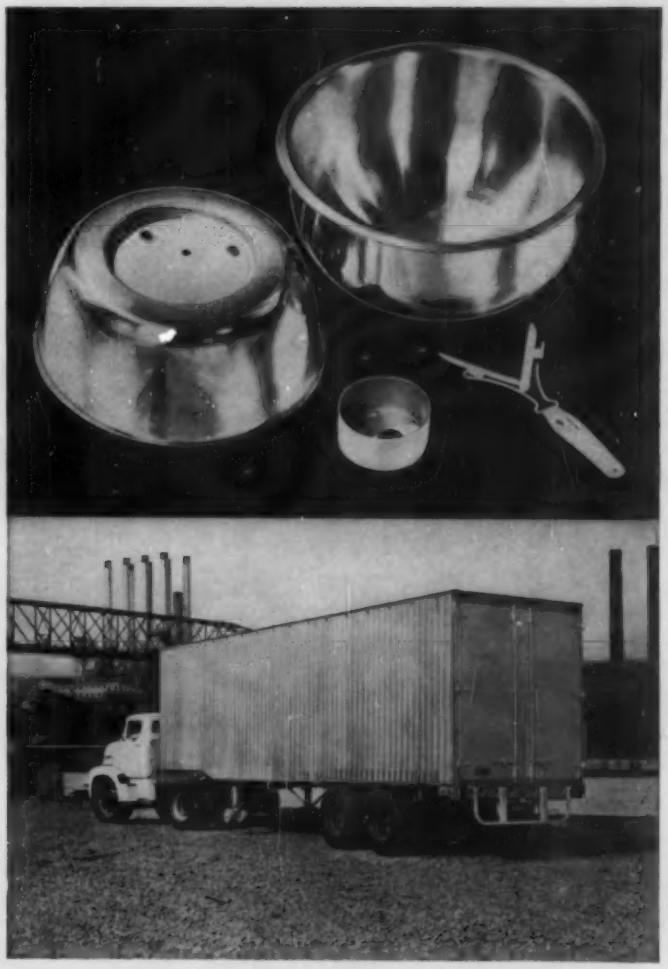
For special applications like this, get in touch with Mr. Tubes, whose specialty is matching tubes to jobs to save you time and money. For many Electric-Resistance-Welded tubing requirements, you'll find that your nearby B&W distributor maintains comprehensive stocks to meet your needs. The Babcock & Wilcox Company, Tubular Products Division, Beaver Falls, Pa.

Seamless and welded tubular products, seamless welding fittings and forged steel flanges in carbon, alloy and stainless steels

You can draw and form them LITTLE

. . . . . .

or fabricate them BIG



with the new A-L low-nickel STAINLESS GRADES

WRITE FOR THE ASSISTANCE YOU NEED

1. "TECHNICAL STUDIES #3"

. . . essential information on the composition, properties, fabricating methods and applications of AL chromium-manganese, low-nickel stainless steels. *Write for your copy.*

2. TEST SAMPLES

. . . We'll be glad to supply engineering assistance, and actual samples of these 200-Series steels for testing under your processes and conditions.

ADDRESS DEPT. MP-86

In the top photograph, the fabrications you see are a mixing bowl, a tea-kettle base, a lock case and a patented shoe fastener: all made of A-L Type 201 or 202 chrome-manganese low-nickel stainless. The finish is good, the steel handled the same in the presses as Types 301 or 302, and similar drawing, buffing and polishing procedures were followed.

As in the lower illustration, the chrome-manganese low-nickel grades are being used also for fabrications as large as truck trailers and railroad coaches. Again, forming qualities and weldability present no problems, and results are entirely satisfactory.

Sum it all up and this is the answer: you *won't* encounter any particular differences in fabricating the 200-series of stainless steels . . . you *will* find some advantage in price, and a very important factor of much greater availability in times of nickel shortage. ● Why not take advantage of our pioneering experience with the low-nickel grades—let us help you use them. ***Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa.***

WSW 6060

For Stainless Steel in ALL Forms—call

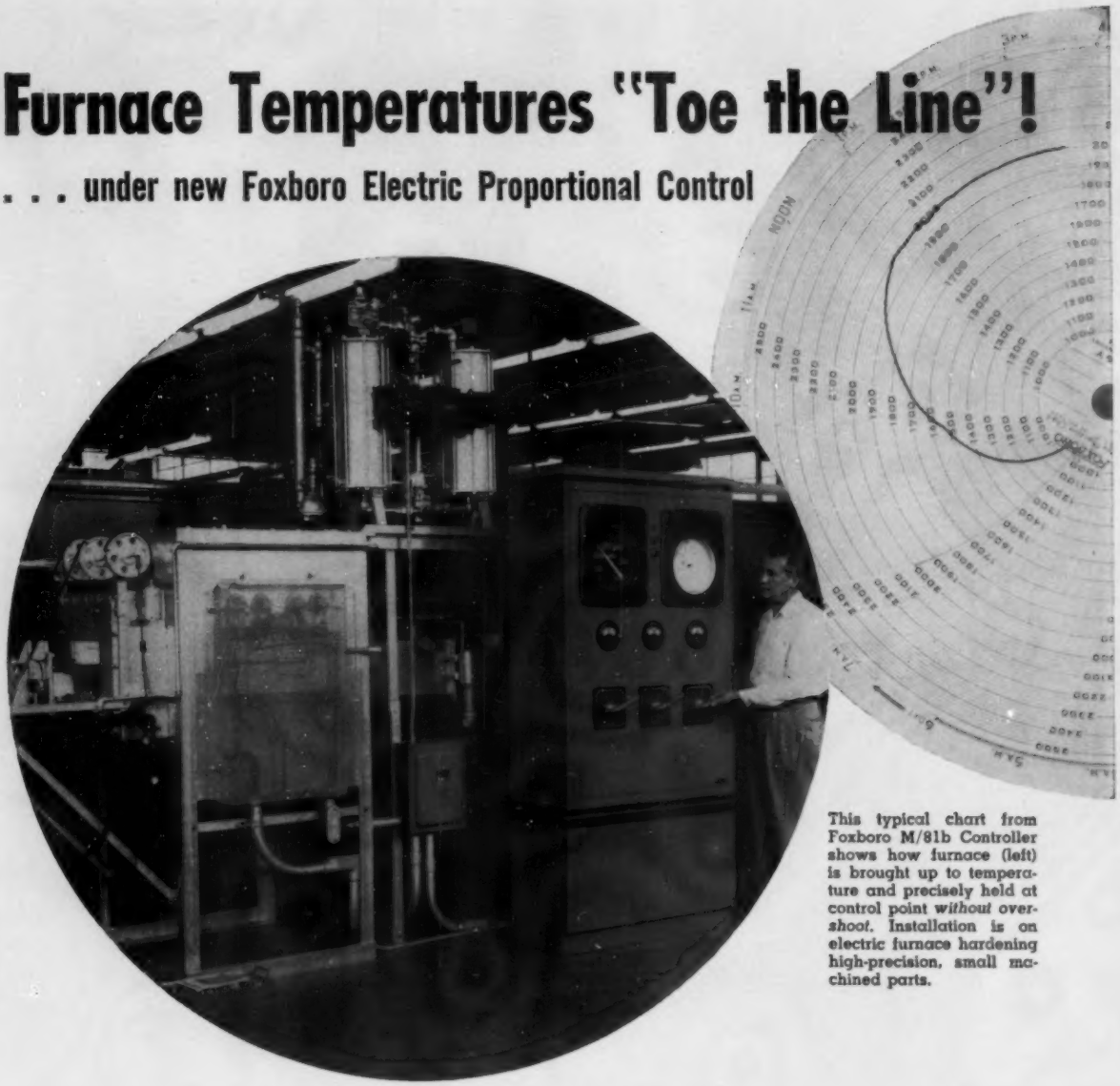
Allegheny Ludlum

Warehouse stocks carried by all Ryerson Steel plants

AL® STAINLESS STEEL

Furnace Temperatures "Toe the Line"!

. . . under new Foxboro Electric Proportional Control



This typical chart from Foxboro M/81b Controller shows how furnace (left) is brought up to temperature and precisely held at control point *without* over-shoot. Installation is on electric furnace hardening high-precision, small machined parts.

Heat treating temperatures stay right on the control line when the new Foxboro M/81b Electric Proportional Controller handles furnace heat input. This fast-acting Controller assures the furnace a "balanced diet" of B.T.U.'s despite upsets, load changes, furnace lags, or ambient temperatures.

Control action is simple — effective. The M/81b senses any tendency of temperature to move away from pre-set control point . . . automatically varies ratio of heat "time-on" to "time-off" depending on changes in furnace loading. This *Proportional-set Average-position Controller* eliminates over- and under-shoot . . . maintains unusually uniform furnace conditions.

For top performance from your electrically heated or fuel-fired muffle-type furnace . . . new or modernized . . . investigate Foxboro Electric Proportional Control. Write for Bulletin 4-11.

THE FOXBORO COMPANY, 522 NEPONSET AVENUE, FOXBORO, MASSACHUSETTS, U. S. A.

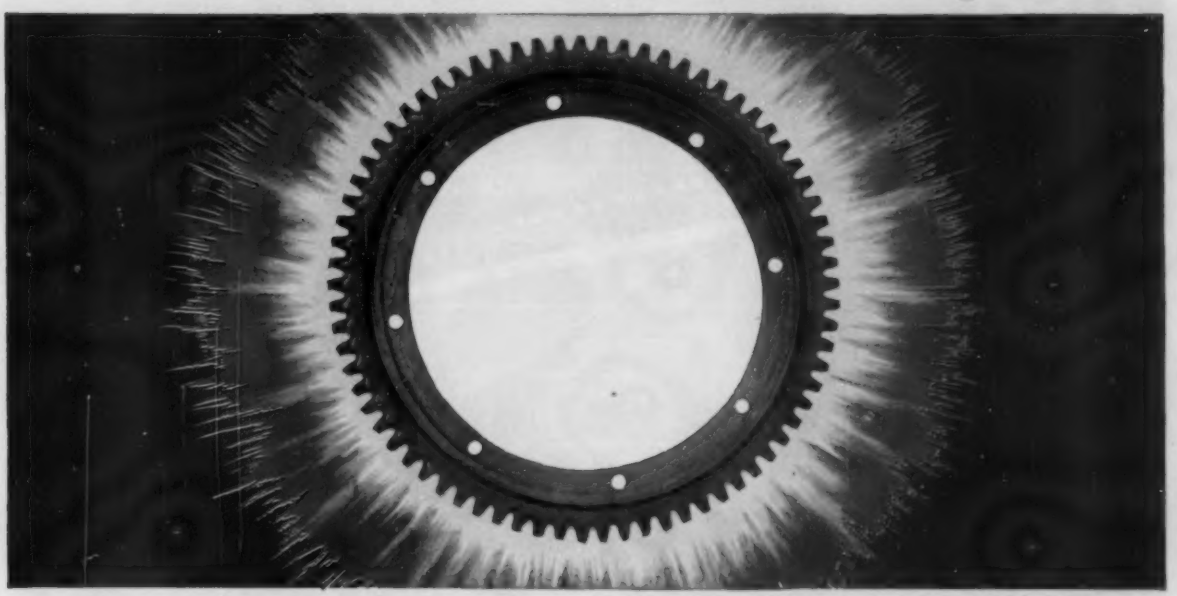
FOXBORO
REG. U. S. PAT. OFF.

Electric
Proportional Controllers

FACTORIES IN THE UNITED STATES, CANADA, AND ENGLAND

IH Saves $82,507 Per Year

with TOCCO* *Induction Hardening*



Gears, shafts, pins, wheels, tubes and bars—almost any size or shape of part—or any metal, too—is adaptable to TOCCO hardening, brazing, annealing or heating for forging.

Production Up—Engineers at the Milwaukee Works of International Harvester Company have adopted TOCCO for hardening final drive gears for famous International Harvester farm tractors. TOCCO increases production on the gear shown here from 14 to 35 per hour, 250% faster than conventional heating method, reduces job from a 3 shift to 2 shift operation, even with increased production schedule. Heating time is 35 seconds; oil quench, 60 seconds.

Costs Down—TOCCO cuts cost—saves $82,507 per year on application shown above. TOCCO makes possible use of C-1050 A.R.R. steel instead of expensive A-8645-H alloy steel previously required. TOCCO also eliminates shot-blast, formerly needed to remove scale, and extra machining operations that used to be necessary to compensate for distortion.

Gear shown is 18½" O.D., width of face is 2", weight 34 pounds, 73 teeth. Hardness obtained is 55-66 R.C., using 140 K.W. of 10,000 cycle power.

Our Engineers can probably find applications in your plant where TOCCO can increase output and reduce unit costs.

TOCCO

THE OHIO CRANKSHAFT COMPANY

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Please send copy of "Typical Results of TOCCO Induction Hardening and Heat Treating".

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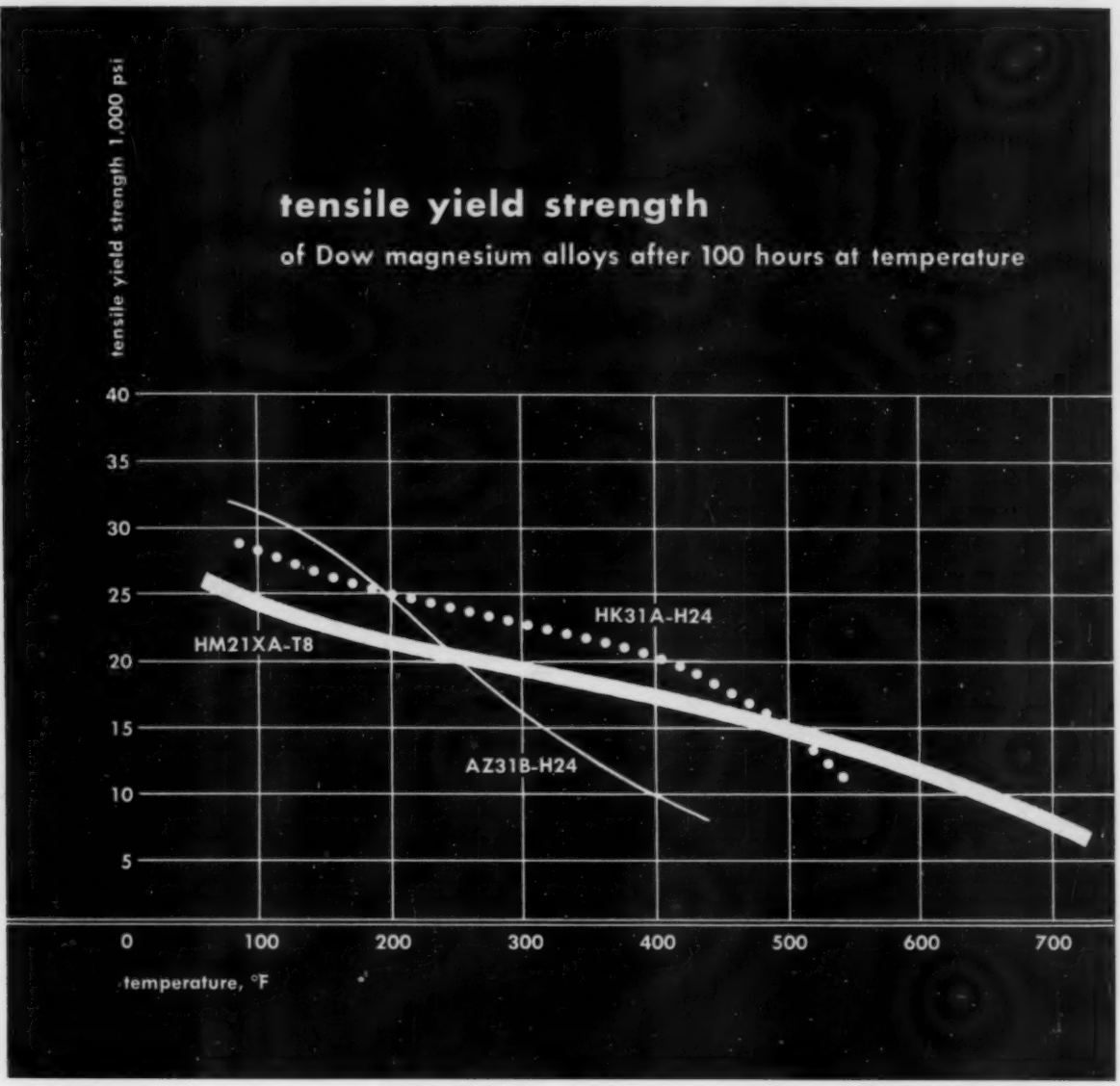


New magnesium alloy holds properties for 100 hours up to 700°F.

Dow Magnesium HM21XA-T8 alloy extends further the range of conditions under which light metals can be used in aircraft design. Second in the series of sheet alloys designed specifically for elevated temperature applications, it supplements the excellent ch .acteristics of HK31A alloy.

HM21XA-T8 retains its properties at temperature during long periods of time. Even one hundred hours at 700°F. results in relatively little change in tensile yield, creep and elastic modulus.

Magnesium lightness is combined with strength at elevated temperature in HM21XA-T8, offering new ways to save weight or gain increased rigidity in the design of missiles and aircraft. This alloy is supplied in the -T8 temper and can be formed in this temper without the need for further heat treatment after fabricating. Samples of HM21XA-T8 along with detailed information are available. Contact your nearest Dow Sales Office or write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Department MA 1400Q.

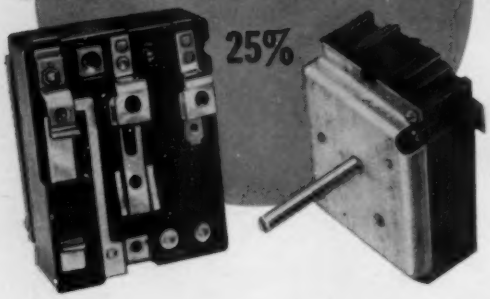
YOU CAN DEPEND ON DOW

Here at Fahralloy we don't have any sidelines. All we do is one thing—make heat and corrosion resisting castings. But we figure that's a full time business in itself. You see, we look at each and every job as something special. We want to be sure it is properly engineered for the service conditions to which it will be exposed. Because of this thorough approach, we've been able to render a service to FAHRALLOY customers far beyond the mere making of a casting . . . one that can be measured in many instances in dollars and cents saved! You'll be pleased with the extra special service that goes with every heat resisting casting that bears the name FAHRALLOY.
Won't you let us serve you soon?

THE FAHRALLOY CO.
150th & Lexington Ave. — Harvey, Illinois
In Canada — Fahralloy Canada, Ltd., Orillia, Ontario

Designed with... Beryllium Copper

SIZE OF PROCTOR ELECTRIC'S RANGE-SWITCH IS REDUCED 25%



In its line of fast heating range controls, Proctor specifies the beryllium copper alloy designated Berylco #10, supplied by The Beryllium Corporation, Reading, Penna. Proctor has discovered in this alloy a particularly ideal combination of physical properties—high fatigue strength, good resilience for spring uses, and excellent electrical conductivity for parts carrying current.

PROPERTIES OF "BERYLCO" 10 STRIP

(½ hard temper, heat treated)

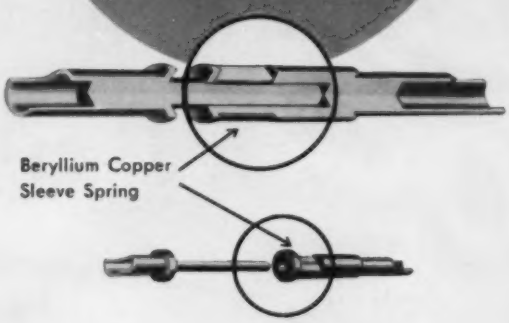
Tensile Strength	110,000 psi (minimum)
% Elongation in 2 in.	5 (minimum)
Rockwell Hardness	
B Scale	95 (minimum)
30T Scale	79 (minimum)
Electrical Conductivity	
% IACS	48 (minimum)
Elastic Modulus in Tension (20°C)	
Before heat treatment	16,000,000 psi
After heat treatment	18,000,000 psi
Elastic Modulus in Torsion (20°C)	
Before heat treatment	6,000,000 psi
After heat treatment	6,800,000 psi

The high tensile strength of beryllium copper eliminates the need for bulky and complicated forms in these parts, thereby permitting a 25% reduction in the unit's size over former models. While the beryllium copper parts constitute only 20% of the weight of the materials employed in the completed range-switch, they are rated 85% in importance by the manufacturer.

In addition to special test requirements of range manufacturers, each switch passes 300 quality control tests at Proctor. In a "mechanical abuse" test, for example, the control shaft is rotated 20,000 times, after which the unit must still operate and maintain its calibration within ±2%.

A technical bulletin (#37), with more specific details on the design and use of beryllium copper for Proctor electric range-switches, is available without charge upon request to The Beryllium Corporation, Reading, Penna.

SLEEVE SPRING IN CANNON PLUG *PRESSURES* FOR MAXIMUM CURRENT FLOW



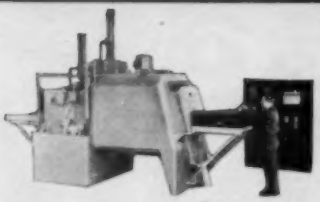
The sleeve spring in a Cannon multi-contact electrical connector forces the pin of the plug tightly against the socket wall to assure maximum consistent current flow. The fatigue strength of the metal used in the spring governs the efficiency and life expectancy of the entire connector. The spring metal must be corrosion resistant, since corrosion would weaken the metal, shortening the life of the spring, and cause wear on the pin of the plug.

In laboratory tests, engaging and separation forces were measured on both beryllium copper and phosphor bronze socket springs when subjected to bending torque from a special test prod. The separation force values after distortion were much lower for the phosphor bronze springs than for the beryllium copper springs. In fact, the phosphor bronze springs failed a number of times, but the beryllium copper springs, made of Berylco #25 alloy, provided consistent pressure even after having been split wide open.

Cannon Electric formerly used phosphor bronze as the spring metal until it conducted tests with beryllium copper. Now Cannon expects to make beryllium copper the standard 'napkin ring' metal on all of its connectors.

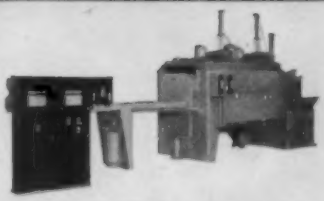
A technical bulletin (#34) is available without cost from The Beryllium Corporation, Reading, Penna. It describes in detail the numerous tests used by Cannon Electric in evaluating beryllium copper as a material for the sleeve springs of its multi-contact connectors.

NOW *there's an Ipsen Standard or Special Heat-Treating Unit just right for your shop*



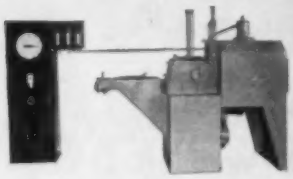
This Ipsen T-400 Automatic Atmosphere-Controlled Unit is the most versatile of all units.

TFC Units for automatic, controlled-atmosphere heating and forced cooling under atmosphere.

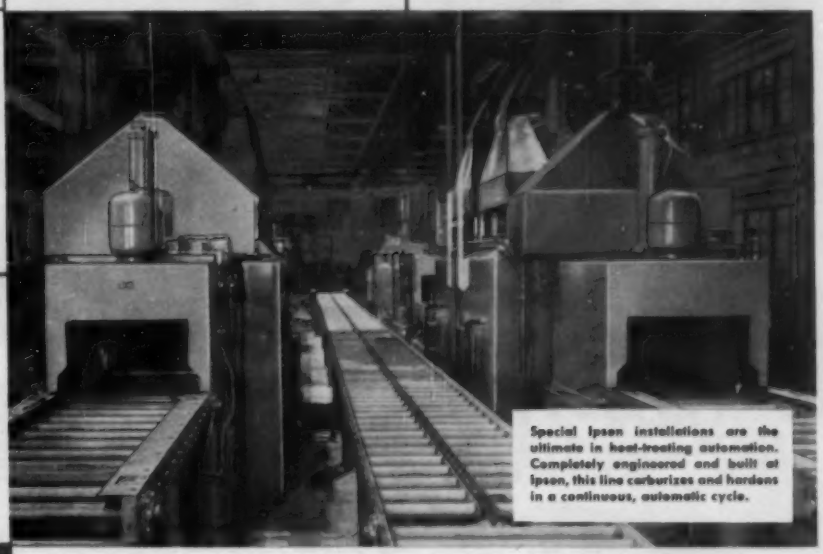


Standard production units with independent heating zones, with capacities up to 3000 pounds per hour.

Ipsen auxiliary equipment . . . gas and electric Generators; Dewtronik and Carbotronik Controllers.



The RT-25-E permits controlled-atmosphere heat treating in the laboratory or tool room.



Special Ipsen installations are the ultimate in heat-treating automation. Completely engineered and built at Ipsen, this line carburizes and hardens in a continuous, automatic cycle.

Whatever your heat-treating requirement may be, now there is an Ipsen Controlled Atmosphere Unit to meet it . . . standard units from 25 to 3000 lbs./hr., or special installations engineered to individual production needs. Experienced metallurgists will analyze and recommend correct procedures. Why not contact an Ipsen sales engineer . . . today!

CALL, WRITE, OR WIRE . . .

IPSEN INDUSTRIES, INC. • ROCKFORD, ILL.

Hartford, Conn.	Burbank, Calif.	Denver, Colo.
Chicago, Ill.	Lakewood, Ohio	Toronto, Ontario, Canada
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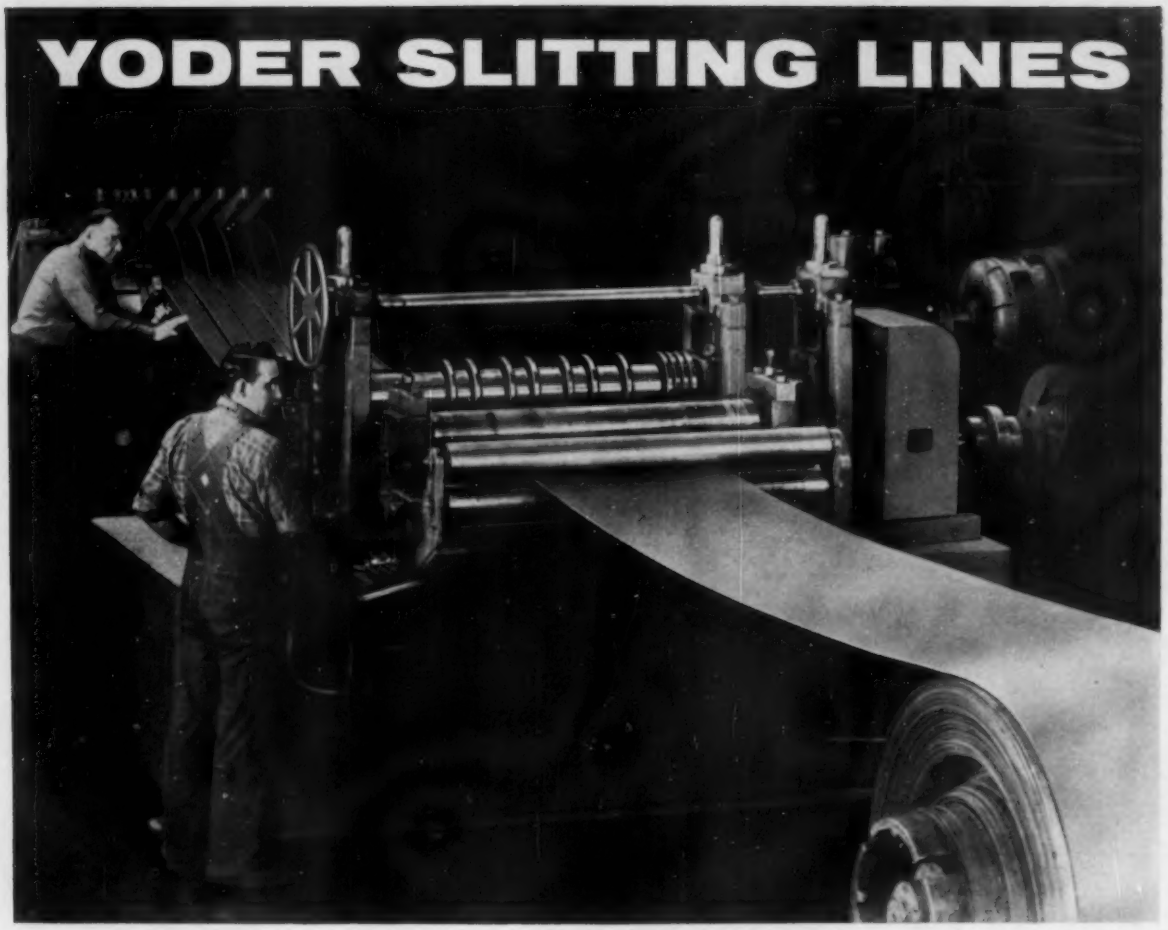
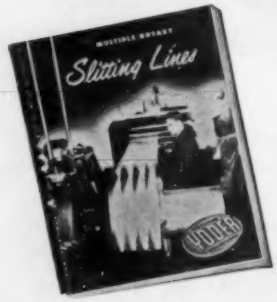
YODER SLITTING LINES



pay big dividends working only one day per week!



The Yoder Slitter Book is a comprehensive treatise on slitter operation and economics, with time studies, cost analyses and other useful data. It is yours for the asking.

In one plant, two Yoder tube mills and about 50 punch presses are being supplied with slit strands by one Yoder Slitting Line operated an average of only *seven hours per week.*

In another plant, a Yoder slitting line, *operated from six to eight hours per week,* is supplying two intermittently operated roll forming machines with total requirements averaging 100,000 feet per week.

These typical examples demonstrate, first, the big potential output of a relatively small, inexpensive Yoder standardized Slitting Line and, secondly, its big profitability. Assume production of only 35 tons of slit strands per 8 hour shift, one day per week, and the total per year would be 1750 tons. Estimating the saving in slitting cost at only one-half cent per lb., the total annual saving would be $17,500.00.

Besides the big convenience of doing your own slitting, such savings will often repay the investment in a few months.

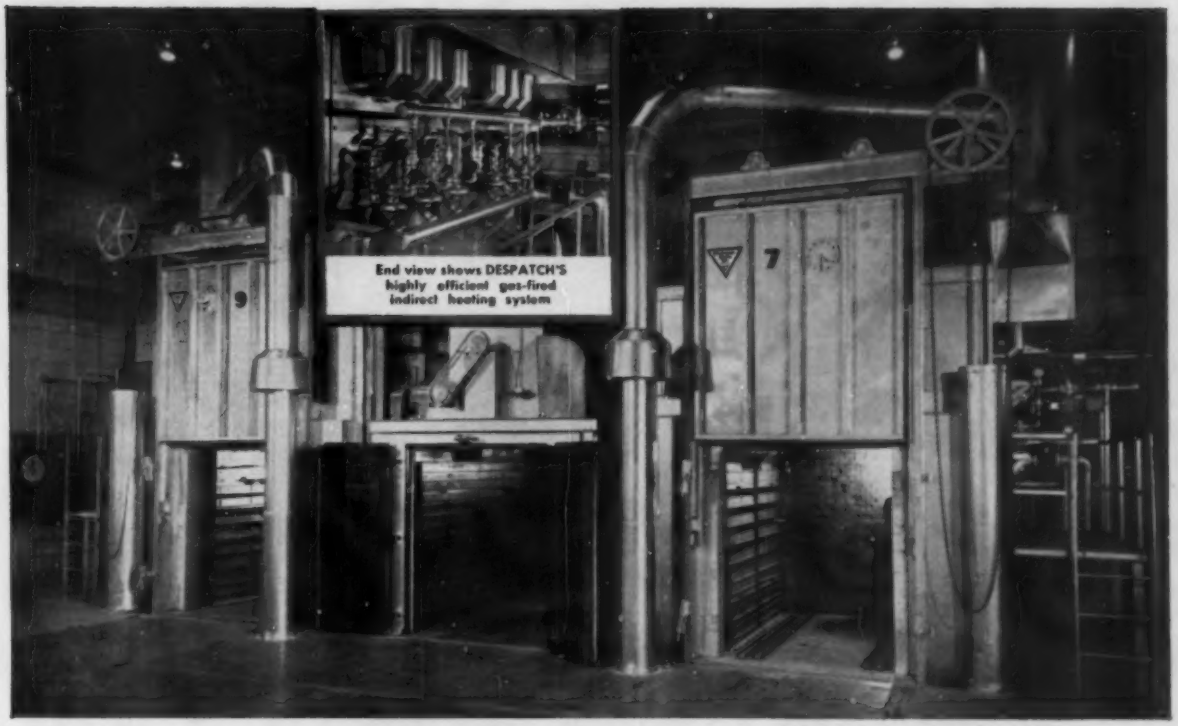
THE YODER COMPANY 5595 Walworth Avenue • Cleveland 2, Ohio, U.S.A.

ENGINEERING YODER MANUFACTURING

ROTARY SLITTING LINES

COLD ROLL FORMING MACHINES

ELECTRIC-WELD PIPE AND TUBE MILLS



For solution heat treating of ALUMINUM *industry demands fast, uniform* FURNACES *engineered for top production by* DESPATCH

When uniformity counts most . . . within ±2° . . . on load after load after load . . . that's when manufacturers such as R. C. Hitchcock & Sons call on DESPATCH for furnaces with the uniformity, economy and flexibility needed to meet the exacting requirements of today's aluminum alloy heat treating.

Shown above is the latest addition to the firm's heat treating facilities. This installation, at the Hitchcock Plant No. 2 in Bloomington, Minn., boosts their total to nine such furnaces by DESPATCH. The equipment is fully automatic; operating at 1000° F., ±2° on a 12-hour cycle with no manual assistance necessary.

DESPATCH's wealth of experience assures you the highest standard of performance. There's a DESPATCH-trained resident engineer near you. Why not talk to him about your furnace requirements?

DESPATCH OVEN COMPANY

619 Eighth St. S. E.
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Sales and Service in
All 26 Principal Cities

Write for Bulletin 81P

PIONEERS IN ENGINEERING HEAT APPLICATIONS FOR INDUSTRY

XERORADIOGRAPHY

a new x-ray process to make your products better

Cuts x-ray exposure-to-image time to 1 minute

With the commercial introduction of xeroradiography *(pronounced zero-radiography)* General Electric puts quality control on an economical, production-line basis. Thanks to the high speed and low cost of this new process, it is now practical to perform 100% x-ray inspection of light-alloy castings, weldments, small assemblies—in fact any product which can be radiographed with relatively short exposure.

Visible image in 1 minute

Box at right shows how xeroradiography works. There are three methods of utilizing this new inspection tool:

(1) Image can be viewed directly on original plate.

(2) Film record can be made by photographing the plate.

(3) Permanent paper "print" can be made directly from the plate.

All three are fast—permit immediate corrective measures before a large number of defective parts have been processed—give you a radiographic image well within the accepted 2% sensitivity.

Xeroradiography offers dramatic cost reductions:

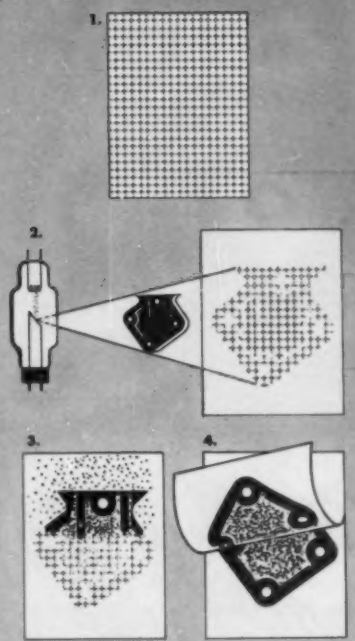
Reusable plates — Merely clean and recharge. Cost is less than half that of conventional film.

No darkroom — All operations are performed in the light. No solutions, no liquid chemicals, no tanks, no plumbing, no lead-lined storage bins.

Greatly reduces x-ray inspection time —Defective parts are detected within seconds. Ends useless machining.

Lower first cost — Xeroradiographic equipment costs far less than that needed for automatic film processing.

How xeroradiography process works...

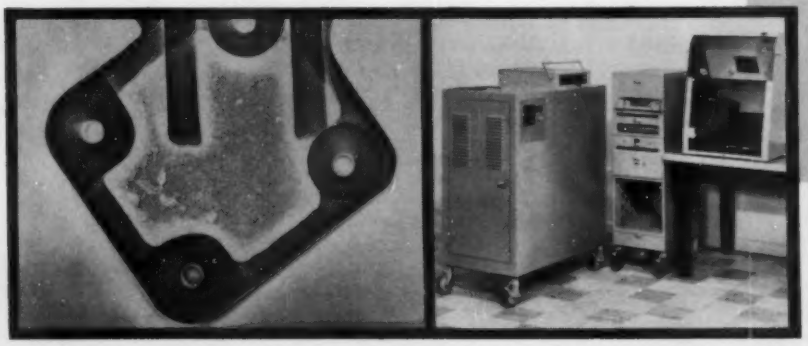


1. Aluminum plate, coated with photo-sensitive selenium, receives positive charge which is lost when exposed to x-rays.

2. X-rays penetrate specimen as in conventional radiography. Charge on plate "leaks" away proportionately to degree of x-radiation.

3. Negatively charged powder from spray gun adheres to positively charged area. Density varies with amount of charge. Image can be viewed directly, copied on film record, or transferred to paper.

4. Print can be made by pressing special paper on plate by rollers. Powder from plate is transferred, giving a positive image which is fixed permanently by applying heat. Plate is cleaned for re-use.



Xeroradiographic print of an aluminum casting. Note clear-cut definition of the dispersed porosity in the central section.

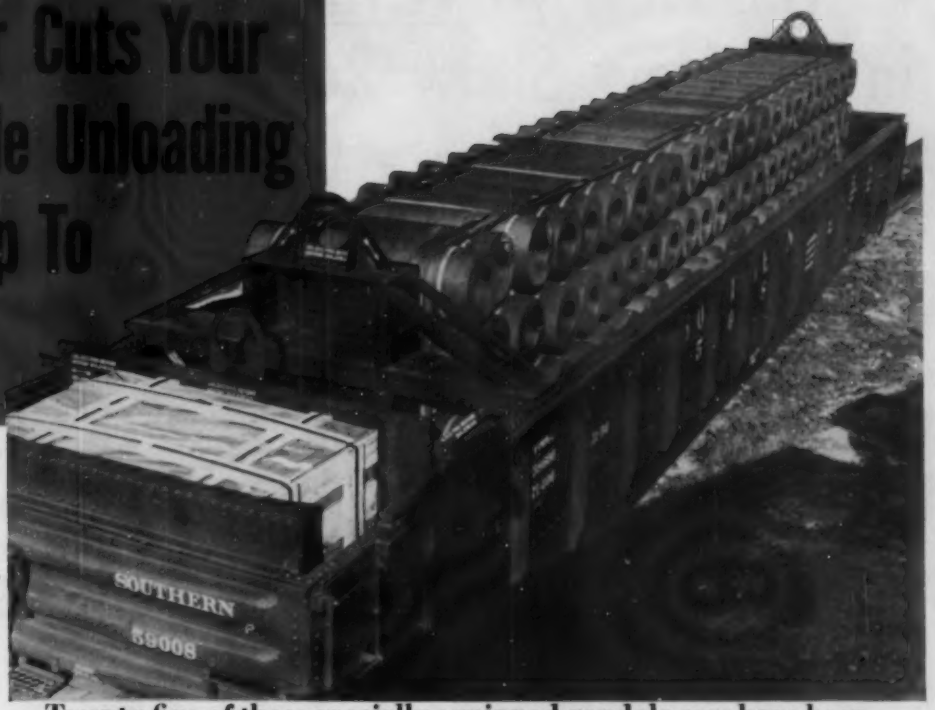
Xeroradiographic equipment (l. to r.): development unit, cleaner-cycler-charger-storage unit, accessory viewing unit.

If time or cost factors have prevented you from adopting x-ray for your inspection needs, ask your G-E x-ray representative about xeroradiography. Or write X-Ray Dept., General Electric Co., Milwaukee 1, Wis., for Pub. AS-24.

Progress Is Our Most Important Product

GENERAL ELECTRIC

This Car Cuts Your Electrode Unloading Costs Up To 80%



Twenty-five of these specially equipped gondola cars have been placed in service by Southern Railway System to handle graphite electrode shipments from the Great Lakes Carbon Corporation plant in Morganton, N. C.

• • •

Exhaustive tests conducted during actual electrode deliveries proved conclusively that the new cars save up to 80% in costs, as compared with other methods.

Three unique devices in the new cars are responsible for these amazing results. An adjustable bulkhead quickly compensates for differences in electrode shipments. At the other end of the car, a self-adjusting bulkhead automatically moves forward to take up any slack that might develop en route. Another movable bulkhead offers safe stowage for the accompanying nipples.

These specially equipped electrode cars effect their savings through substantially reduced labor costs, less crane time and the virtual elimination of dunnage.

We wish to express our appreciation to Southern Railway System for its splendid cooperation in helping us effect these savings for our customers.

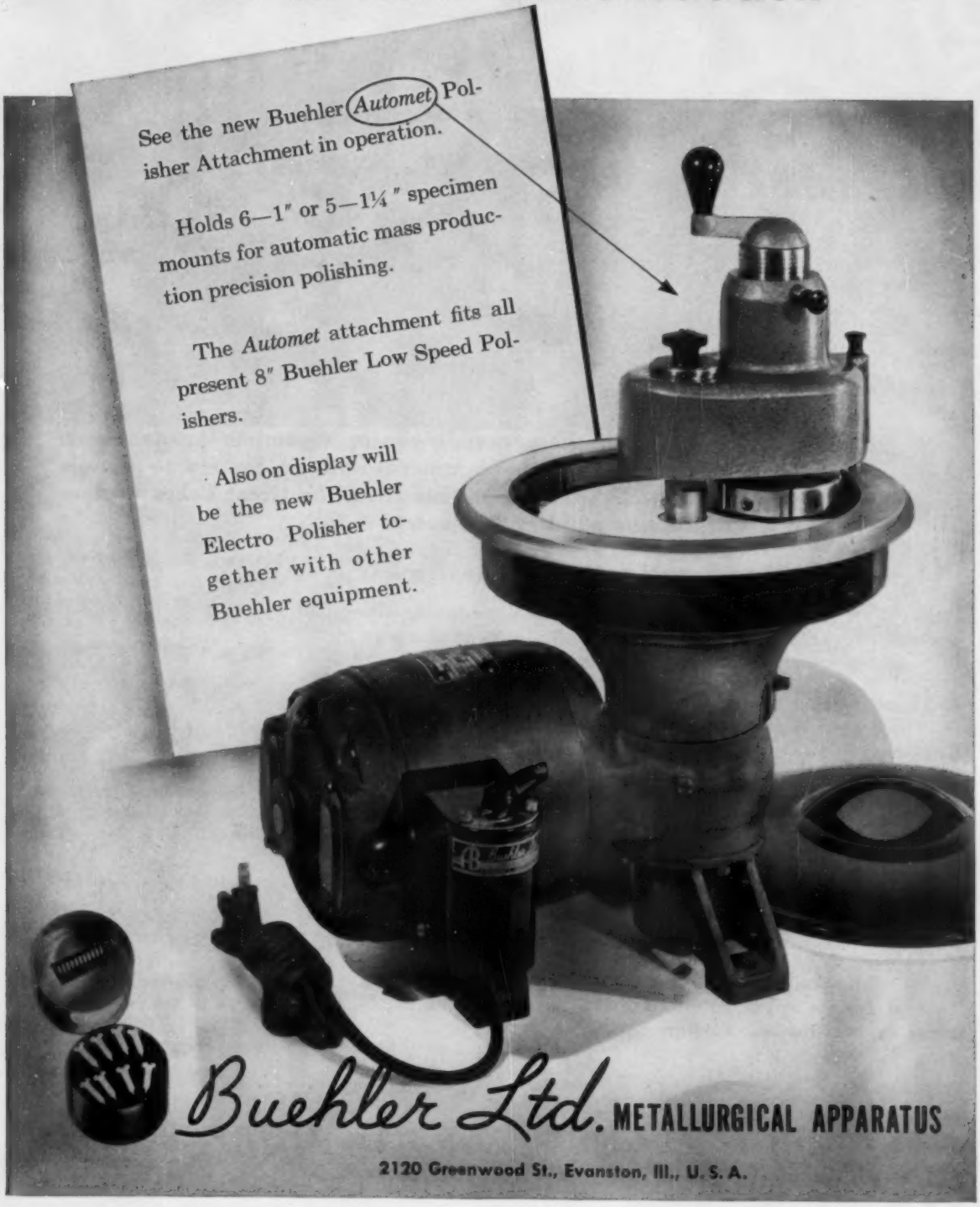
This legend signifies another major Great Lakes Carbon Corporation contribution to electric steel progress.

ELECTRODE GLC® DIVISION

GREAT LAKES CARBON CORPORATION

18 EAST 48TH STREET, NEW YORK 17, N.Y. • OFFICES IN PRINCIPAL CITIES

The New AUTOMET is on Display in our New Show Room and Laboratory Visit us for a Demonstration


See the new Buehler Automet Polisher Attachment in operation.
Holds 6—1" or 5—1¼" specimen mounts for automatic mass production precision polishing.
The Automet attachment fits all present 8" Buehler Low Speed Polishers.
Also on display will be the new Buehler Electro Polisher together with other Buehler equipment.
Buehler Ltd. METALLURGICAL APPARATUS
2120 Greenwood St., Evanston, Ill., U. S. A.

VANADIUM-ALLOYS STEEL COMPANY

Presenting

an improved tungsten

Die Steel for Hot Work

with these definite superiorities:

- High resistance to thermal fatigue
- Longer die life on extrusion dies
- Outperforms standard 9.50% tungsten steels on many applications

WCC—the new tungsten, chromium, cobalt and vanadium hot work die steel—offers higher physical properties at elevated temperatures than standard 9.50% tungsten grades, and is distinguished by greater resistance to heat checking. Its cobalt content steps up hot hardness and tensile strength at high temperatures. Its vanadium content also aids hot hardness and definitely increases resistance to wear and thermal fatigue. • You'll find WCC delivers measurably better performance on a host of jobs where 9.50% tungsten had been considered standard for years . . . just specify this *modern* hot work die steel on that next job coming up!

Write for the new WCC Data Sheet—facts and figures you can use!

Vanadium-Alloys Steel Company

Latrobe, Pennsylvania

SUBSIDIARIES: Colonial Steel Co. • Anchor Drawn Steel Co. • Pittsburgh Tool Steel Wire Co. • Vanadium-Alloys Steel Canada Limited • Vanadium-Alloys Steel Societa Italiana Per Azioni

XIX

This is the nineteenth of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Determining the Proper Depth of Case in Alloy Steels

In the previous article of this series we discussed the carburizing of alloy steels, pointing out that the purpose of carburizing is to provide a hard, abrasion-resistant outer shell or "case." Such a discussion naturally gives rise to the question, What factors influence the choice of case? Should it be shallow? Medium? Deep or extra-deep?

While it is not always wise to formulate hard-and-fast rules, the following may be used as a general yardstick:

Shallow cases (less than 0.02 in.). Suitable where wear-resistance alone is the chief requirement, and where good surface condition after heat-treating is advantageous. Not suitable if high stresses are apt to be encountered in service.

Medium cases (0.02 to 0.04 in.). For high wear-resistance. Will stand up under substantial service loads and stresses. The thickness is sufficient to permit certain finishing operations, such as light grinding.

Medium-to-deep cases (0.04 to 0.06 in.). For high wear-resistance. A case in this depth range is essential where continuing friction is involved, especially friction of an abrasive or semi-abrasive nature. It is also a good precautionary measure where application of the finished part may sometimes involve crushing action.

Extra-deep cases (more than 0.06 in.). Cases of this depth can be obtained by extending the furnace time in pack carburizing. Highly wear-resistant, they also withstand shock and impact. A large camshaft of an internal-combustion engine is a good example of a part requiring the extra-deep case. This is of course particularly true of the cam lobes themselves.

If you require specific advice concerning case-hardened parts, by all means communicate with our Metallurgical Division. Bethlehem technicians are always on call, and you can depend on their recommendations. And you can depend on Bethlehem, too, when seeking new supplies of alloy steels; for Bethlehem makes the full range of AISI standard grades, as well as special-analysis steels and all carbon grades.

If you would like reprints of this series of advertisements from No. I through No. XVI please write to us, addressing your request to Publications Dept., Bethlehem Steel Company, Bethlehem, Pa. The first 16 subjects in the series are now available in a handy 32-page booklet, and we shall be glad to send you a free copy.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

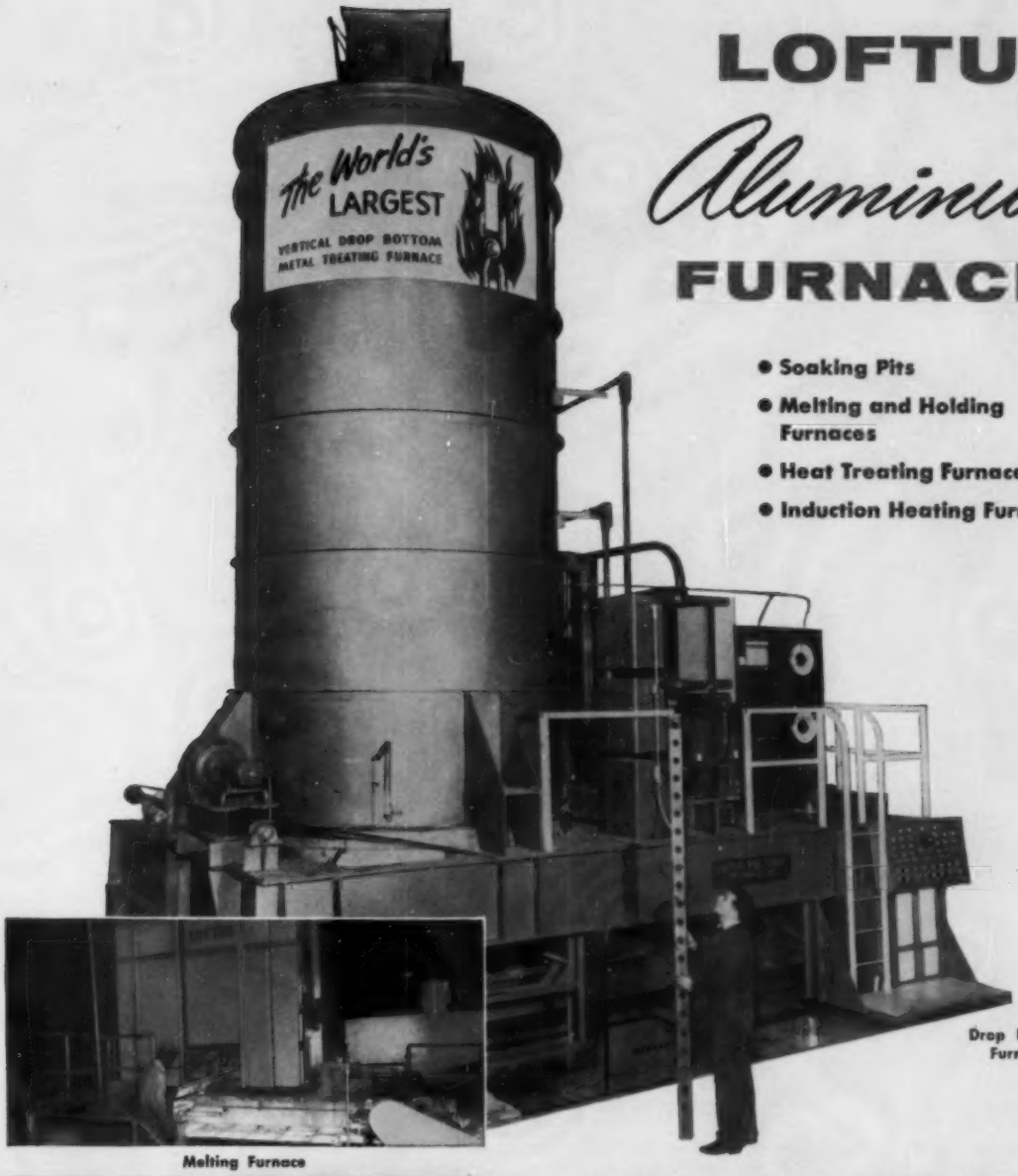
On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

LOFTUS *Aluminum* FURNACES

- Soaking Pits
- Melting and Holding Furnaces
- Heat Treating Furnaces
- Induction Heating Furnaces



Drop Bottom Furnace

Melting Furnace

Soaking Pits

As designers and constructors of the most modern, efficient furnaces for the aluminum industry, Loftus recently completed the world's largest Vertical Travel Type Drop Bottom Metal Treating Furnace. Commenting on this ultra-modern installation, our customer says: "Loftus can be proud of pioneering this type of furnace for the metal treating industry." Whatever your furnace requirements, you can depend on Loftus for the best possible heating at the lowest possible cost.

Write today for complete details

Loftus ENGINEERING CORPORATION
Designers and Builders of Industrial Furnaces

610 Smithfield Street, Pittsburgh 22, Pennsylvania
140 S. Dearborn St., Chicago, Ill.

WHAT'S AHEAD...

in steel service and supply

NEW STEELS—Dozens of new sizes and new types of steel have been added to Ryerson stocks in recent weeks—or will be added in the immediate future. Among these products are:

- New Type 202 Allegheny stainless sheets in more gauges
- 8620 alloy plates
- Cold finished leaded Rytense bars (medium-carbon manganese steel)
- Rycut bars (leaded alloy) in greatly increased size ranges
- A west coast stock of fluid power tubing (including hydraulic fluid line tubes to JIC *and* AMS-5050 specs.) previously carried only at our eastern and midwest plants
- Leaded C1141 in cold finished rounds

These are just a few of the additions that make the world's largest steel stocks even larger and make steel buying quicker and more convenient.

NEW QUALITY SAFEGUARDS—A quality control system even more comprehensive than before includes among many new safeguards:

- A more scientific color code that makes steel identification more error proof
- Tolerance control of tubing for cylinder applications that allows you to order more accurately to O.D. and *I.D.* instead of to the customary O.D. and wall

In all, scores of controls will assure the dependable quality of Ryerson steels in 1957.

STEEL SUPPLY OUTLOOK—Demand for most thicknesses of carbon steel plates, heavy structurals and flat rolled 18-8 stainless will undoubtedly continue to exceed supply—but *all* other steels are in good supply at Ryerson and should remain in good supply during the entire year.

STEPPED-UP SERVICE—In 1957 better than five out of every six orders for steel from Ryerson stock will be shipped within 24 hours—and when emergency demands we can send steel on its way to a customer in an hour or two. Service in the Indianapolis and Charlotte areas will be further improved with the completion of new Ryerson plants in these cities during 1957. And we are enlarging and modernizing—adding new equipment—from coast to coast so that we may always be able to supply the steel you need, exactly when you need it.

So here's our steel-service pledge to you for 1957—an even wider selection of steels, even more safeguards to assure dependable high quality, and service that always meets your requirements—now and throughout the year.

RYERSON CERTIFIED QUALITY

RYERSON STEEL

In stock: Carbon, alloy and stainless steel . . . bars, structurals, plates, sheets, tubing, reinforcing bars, machinery & tools, etc.

JOSEPH T. RYERSON & SON, INC. PLANTS AT: NEW YORK • BOSTON • WALLINGFORD, CONN. • PHILADELPHIA • CHARLOTTE • CINCINNATI CLEVELAND • DETROIT • PITTSBURGH • BUFFALO • CHICAGO • MILWAUKEE • ST. LOUIS • LOS ANGELES • SAN FRANCISCO • SPOKANE • SEATTLE

Metal Progress
Volume 71, No. 2 February 1957

Insuring Toughness in Forged Gun Tubes

*By A. HURLICH and A. F. JONES**

Composition of steel for large gun forgings is not specified. Heat treatments can be adjusted by the manufacturer to meet required ductility (reduction of area) and toughness (Charpy impact at −40° F.). Soundness is determined by macro-etching. (Q23, Q6, Jgeneral, ST, 4-1, 15-24)

THE RECENT SPATE of unexpected brittle failures of rotor forgings, described in a series of articles in *Metal Progress* starting in February of 1956, has focused attention on the many problems associated with the production of such large pieces of heat treated steel, and started intensive studies by both the producing and using industries to determine the causes of brittle fracture of large forgings, to develop preventive practices, and to devise suitable criteria for evaluating the tendency of material to fail in a brittle fashion.

The Army Ordnance Corps has had extensive experience with large gun tubes and cannon components, has conducted many studies into the causes of brittle fracture and the relationships between the metallurgical factors, the mechanical properties, and the service performance of cannon, and has written specifications intended to incorporate the quality requirements necessary to minimize the possibility of brittle fracture under high impact. This article summarizes some of our experiences with large gun forgings and attempts to relate them to the problems encountered in large rotor forgings.

A comparison of the sizes and weights of two of the large rotor forgings which failed by brittle fracture and large gun forgings for the U.S. Army is given in Table I. It is evident that the largest Army gun forgings are about half the weight and from one third to one half the diameter of large forgings for electrical generators. The latter are made from ingots weighing from 200,000 to 300,000 lb. and up to 100 in. across at the top. The largest Army gun forgings are from ingots

*At the time of writing this paper, Mr. Hurlich was chief of the Materials Engineering Laboratory and Mr. Jones was chief of the Materials Utilization Division of the Ordnance Materials Research Office, both at Watertown (Mass.) Arsenal. Mr. Hurlich is now with the aero-physics group of Convair Astronautics Div., General Dynamics Corp., San Diego, Calif. The statements and opinions printed in this paper are the views of the authors, and do not necessarily represent the official view of any branch of the armed services.

Table I – Sizes and Weights of Large Rotor and Gun Forgings

Component	Length	Max. Diameter	Weight
Tanners Creek turbine wheel	19 ft.	61 in.	72,000 lb.
Cromby generator rotor*	36	43	118,000
155-mm. gun (rough forging)	25.5	15	10,500
8-in. howitzer (rough forging)	19	18.5	15,500
8-in. gun	35	19	25,000
240-mm. howitzer	27	24	30,000
280-mm. gun	50	21	40,800

*Largest generator rotor forging ever made in the U.S.

weighing up to 100,000 lb. and 55 in. across.

Notwithstanding the size and weight differentials, many of the metallurgical and processing problems are quite similar in nature and magnitude. Significant differences in the way the two products are made will be pointed out and inferences will be drawn as to the relationships these processing variables may have to the brittle fracture problem.

Steelmaking Practices

The great majority of large caliber Army guns, such as those listed in Table I, are now made from basic electric steel. Basic openhearth and acid openhearth steels have also been used, but to a relatively limited extent. Ordnance experience has shown that it is generally easier to meet "toughness" requirements with basic than with acid steels because basic steel usually has lower average sulphur and phosphorus. We have found that when sulphur and phosphorus are reduced from a range of 0.025 to 0.040% for each element to a range of 0.010 to 0.015%, a significant increase in the notched-bar impact resistance of heat treated steels has resulted, everything else being the same. The susceptibility to temper embrittlement is also markedly influenced by a change in phosphorus content between these ranges. For these reasons, basic steel is being increasingly used for Army equipment requiring maximum resistance to shock loading and to brittle fracture in service.

It is true that some of the rotor forgings which failed were also made from steels refined in basic-lined furnaces, but, as will be discussed later, other significant differences exist in the processing of large gun and rotor forgings.

Cropping of Ingots – The relationship between weight of rough gun forgings to weight of original ingot is quite uniform over a wide range of gun calibers, namely, 50 to 58%. Similarly, the hot tops of ingots for gun forgings vary within the narrow range of approximately 15 to 20% of the total ingot weight. There are, however, rather wide variations in top and bottom discards – the top discard ranges from approximately 12 to 30% and the bottom crop from 8 to 16% of the total ingot weight.

Heat Treatment After Forging

The typical post-forging heat treatment of large *rotor* forgings includes one or more normalizing cycles followed by tempering and very slow cooling periods, altogether aggregating some hundreds of hours of heating and cooling cycles.

These treatments are intended to homogenize the macrostructure and microstructure, to minimize the tendency toward flake formation and hydrogen embrittlement, and to minimize residual stresses set up by thermal and transformational gradients. The very slow cooling of massive steel structures results, of course, in a very coarse pearlitic microstructure, often with free ferrite rejected at grain boundaries. Since large rotor forgings are not subsequently liquid quenched, this coarse pearlitic microstructure remains the final structure of the part in service.

Large *gun* forgings are also subjected to carefully controlled thermal cycles to avoid flaking and hydrogen embrittlement as well as to promote machinability. (The rough forging is machined down to almost final dimensions prior to final heat treatment.) The length of time consumed in these heat treatments is generally measured in tens of hours as compared to the hundreds of hours for the large rotor forgings, but the sequence of heating and cooling cycles is often the same.

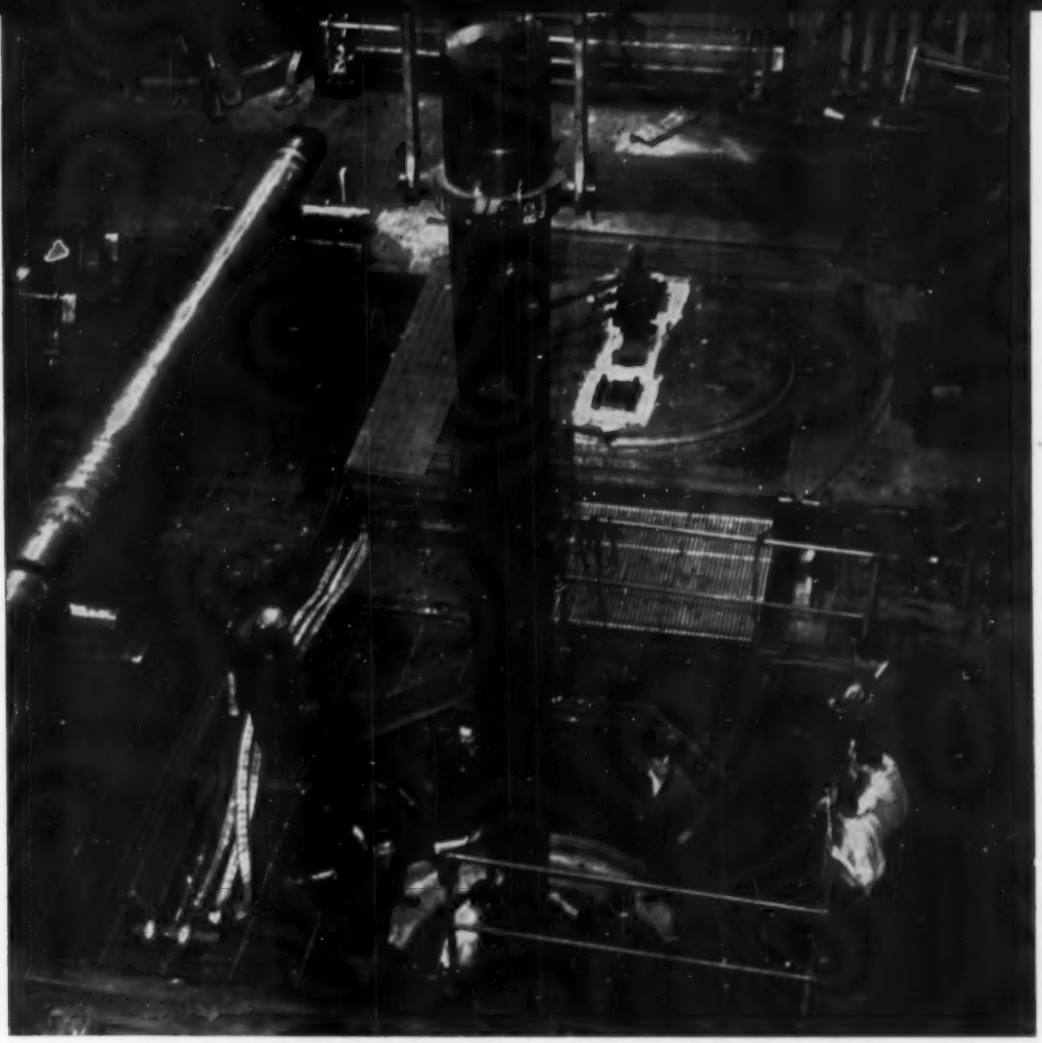
Typical heat treatment after forging a gun tube may be one of the following:

1. Charge hot forging into furnace, heat to 1750° F., hold 10 hr., air cool, reheat to 1225° F., hold 15 hr., furnace cool.

2. Charge hot forging into furnace at 1200 to 1300° F., furnace cool to 600° F., reheat to 1500 to 1700° F., furnace cool to 600 to 800° F., air cool.

3. Charge hot forging into furnace, equalize at 1450° F., cool at 30° per hr. to 450° F., heat to 1750° F., hold 12 hr., air cool, reheat to 1225° F., hold 12 hr., furnace cool.

4. Bury hot forging in ashes and cool to 400 to 500° F., heat to 1700° F., hold 24 hr., furnace cool 24 hr.



Type of Vertical Furnace Used for Heat Treating Gun Tubes. The one shown is really a "shrinkage pit" where warmer reinforcing sleeves will be shrunk on the breech end. Photo by U.S. Army Signal Corps

The above heat treatments result in a microstructure of partially spheroidized coarse pearlite, often with free ferrite at grain boundaries. This results, of course, in low strength levels and high ductility (as measured in the tensile test) and in good machinability. However, the notched-bar impact resistance is extremely low, generally below 10 ft-lb. in the V-notch Charpy test even when the sample is at room temperature.

Final Heat Treatment – All large Army gun forgings are subjected to a liquid quench and a tempering heat treatment after rough machining and prior to final machining. Herein is the major difference in production practices between guns and rotor forgings, since the latter, as made in this country, are not quenched and tempered. Its function is two-fold – to achieve the desired strength level and (most important of all from the viewpoint of resistance to brittle fracture) to achieve the highest possible toughness level by approaching a tempered martensite structure.

Since the sections are large and the cooling rates are slow, and furthermore since the hardenability of the medium-alloy steels that are used is low, the microstructures of the very large gun forgings are generally complex, consisting of mixtures of tempered martensite and bainites. The lower the transformation temperatures at which the bainites form, the closer the approach to the desirable toughness of tempered martensite.

Thus, the large gun forgings are austenitized in the range of 1500 to 1650° F., water quenched, and then tempered at 1100 to 1250° F. The forgings may be held at both temperatures for times varying from 5 to 20 hr. Gun forgings are usually suspended vertically, the breech (larger) end down in the heating furnace and in the quenching tank. This minimizes distortion, and also

gives a somewhat longer time for the heavier end in the quenching medium, hence insuring thorough cooling of the larger cross section. To insure freedom from warping, the forgings are freely suspended by loops welded to the smaller end of the tubes, from pins inserted in collars left on the end discard, or by many similar devices.

The size of the quenching tanks and the rate of water circulation are selected to minimize the temperature rise of the quenching medium. The forgings are generally quenched to below 400° F., either with or without flush quenching of the bore. (Sometimes the bore is flush quenched for a given time before immersion of the whole tube to minimize quench cracking.) By having a rapid flow of cold quenching medium across the surface of the forging – as well as flush quenching of the bore – heat can be abstracted from large bored forgings sufficiently rapidly to avoid transformation to pearlite and large amounts of high-temperature bainites.

Cooling of large gun forgings after tempering may vary; some are air cooled while others are furnace cooled to minimize internal stresses. Slow cooling after tempering may, however, promote temper embrittlement.

Mechanical Properties

After their usual normalize and temper, large rotor forgings possess quite low strengths and high tensile ductilities; values of 85,000 psi. yield strength, 110,000 psi. tensile strength, 20% elongation, and 50% reduction of area may be considered as typical. Their toughness, however, as measured in the V-notch Charpy impact test, is extremely low, 5 to 7 ft-lb. at room temperature, with transition temperatures (change from ductile to brittle behavior) as high as + 200° F. Even with high tensile ductility, such metal offers little resistance to the propagation of a crack, which may take place with explosive speed.

Large Army gun forgings, on the other hand, are heat treated to higher strength levels (to reduce the weight of mobile equipment) and also to obtain high toughness (which tends to prevent brittle fracture). A large forging – say, a 280-mm. gun tube – may have a yield strength of 150,000 psi., tensile strength of 165,000 psi., 12% elongation, 30% reduction of area and a V-notch Charpy impact energy at the mid-wall positions of 12 to 15 ft-lb. at the heavier breech end and 17 to 25 ft-lb. at the lighter muzzle end, the impact tests being conducted at −40° F. At room temperature the impact value may be 5 to 10 ft-lb. higher. If the large gun forgings were to be tempered for longer times at higher temperatures, their strengths would be lower and the ductility and toughness higher.

It is considered particularly noteworthy that while the tensile ductility of the gun forgings (about 30% reduction of area) quoted above is significantly lower than that of large rotor forgings (about 50%), the resistance to brittle fracture is markedly higher. This is due to the microstructure resulting from the liquid quench and tempering. Resistance to brittle fracture is necessary for successful performance of gun forgings and other critically stressed ordnance items. This has been demonstrated time and again, both in the field and in controlled research and development programs, as was pointed out by one of us in a paper on the significance of the V-notch Charpy impact test* as a criterion to evaluate the tendency of steel armor to perform in a ductile or brittle manner under ballistic attack. We have correlated the metallurgical and mechanical properties of such material over a wide range of thicknesses and behavior under service and simulated service conditions.

In addition, some hydraulic fatigue tests conducted at Watertown Arsenal on internally splined hollow cylinders have demonstrated the effect of toughness on fatigue life. Test cylinders having tensile strengths of approximately 140,000 psi. were subjected to cyclically applied hydrostatic pressures of 37,000 and 54,000 psi. until fatigue occurred. One set of cylinders was heat treated to a tempered martensitic microstructure and tested 33 ft-lb. by V-notch Charpy at 70° F. This we call a "tough steel". The second set of cylinders was heat treated to a mixed microstructure of tempered martensite and bainite and had an impact energy of 8 ft-lb. (a "brittle" steel). The following test results were obtained:

	Cycles to Failure	
	37,000 Lb.	54,000 Lb.
Tough steel	8700	5900
Brittle steel	5400	2600

In both tests the tough steel fissured and the brittle steel broke without deformation.

It is recognized that the stress levels were very high in these tests – well *above* the endurance limit – and fracture occurred in relatively few cycles. Engineering structures such as turbine and generator rotors are stressed well *below* the endurance limit and are expected to survive millions to hundreds of millions of stress cycles.

*"Significance of V-Notch Impact Test in Evaluation of Armor Plate", by A. Hurlich; Symposium on Effect of Temperature on the Brittle Behavior of Metals With Particular Reference to Low Temperatures; A.S.T.M. Special Technical Publication No. 158, 1954, p. 262 to 274.

Nevertheless, it must be recognized that intentional or unintentional stress raisers in engineering structures — such as sharp re-entrant angles, changes in section size, improperly machined fillet radii, machine tool scratches, inclusions, segregations, residual pipes and other mechanical and metallurgical defects — may result in local stresses at some points equaling or exceeding the endurance limit. A crack may start at such a location and, in a brittle steel, will propagate with catastrophic violence. If, on the other hand, the steel is tough, local plastic deformation may redistribute the stresses to less dangerous levels, and if a crack does initiate, the inherent resistance to crack propagation may deter, greatly slow down or stop the further growth of the crack.

Ordnance Corps Materials Specifications

Before discussing the details of the specifications for gun tube forgings, it is considered desirable to outline briefly the philosophy upon which the Ordnance Corps' specifications for materials for critical applications are based.

Very early in World War II, metallurgists and engineers for the Ordnance Corps became convinced from studies conducted both in ordnance laboratories and elsewhere that the successful service behavior of a structural part is dictated by its metallurgical and mechanical properties. Chemical composition and method of processing or manufacture in themselves give absolutely no assurance of satisfactory behavior. Accordingly, it was decided that specifications would be based, insofar as possible, upon metallurgical and mechanical properties rather than upon chemical composition and methods of manufacture.

The benefits that accrued from this decision are numerous. The specifications have enabled the Ordnance Corps to obtain vast quantities of material which have performed in a satisfactory manner during World War II as well as in Korea. At the same time, these specifications have given industry the utmost latitude possible in selecting the chemical composition of the steel and the processing methods. This latitude resulted in the manufacturing methods described earlier. They were developed by American industry in a remarkably short time.

Having decided upon the approach that would be taken to the writing of specifications, it became necessary to determine just what properties and characteristics would be required of the material under service conditions. Insofar as gun forgings were concerned, studies of worn-out, failed and intentionally destroyed weapons revealed that the principal characteristics over which control should be exercised were strength, toughness, ductility and steel "quality". An adequate amount of these characteristics insured satisfactory service behavior. The goal was to control these properties through relatively inexpensive laboratory tests rather than through proof firing or simulated service testing.

Strength and ductility can be determined reliably with the static tension test at room temperature. The minimum yield strength specified is based upon design considerations and is selected by the design engineers. The minimum ductility, as measured by the reduction in area in the tension test, is adjusted to the actual yield strength of the steel and the exact values specified are based upon data obtained in correlative studies of service weapons.

For example, for an average yield strength of 150,000 psi. of all the tensile determinations on samples from one end of a large forging, the reduction of area as specified in MIL-S-10458 A (ORD), Military Specification for Steel Forgings for Cannon Tubes and Barrel Components, is:

	Transverse	Longitudinal
Single	>21.0%	>38.0%
Average of two	18.0	36.5
Average of three or four	16.0	34.5
Average of five or more	15.5	34.0
Minimum individual value for multiple tests	12.0	32.0

At first glance these requirements may appear to be somewhat lower than is normally encountered in good quality steel. However, they are sufficiently high to assure steel of *adequate* quality, and at the same time exclude steel containing hydrogen (which is known to reduce ductility and has led to unsatisfactory service performance).

"Quality" of the steel is also controlled by the macro-etch test. In addition, this reveals the presence of such objectionable defects as cracks and flakes.

Toughness — The method for insuring adequate toughness was the subject of considerable study. Extensive research on the mechanical behavior of steels and on the interrelationships between their mechanical and metallurgical properties had demonstrated that lowering the testing temperature produces a tendency toward brittle fracture, in the same manner as raising the velocity of impact or increasing the complexity of the stress system, such as introducing biaxial or triaxial stresses. Thus, a moderately slow-speed test (Charpy impact) conducted at subzero temperatures reveals whether steel will perform in a ductile or brittle fashion when subjected to

dynamic loads such as encountered in guns at atmospheric temperatures. The stress concentration factor provided by the notch further multiplies the effective strain rate in the V-notch impact test, and also introduces a more complex stress distribution.

As a result of the work, it was decided that the V-notch Charpy impact test was the most suitable for differentiating between tough and brittle steels for cannon forgings. Originally, ordnance specifications required a 70° F. testing temperature. However, as service requirements became more stringent, it became necessary to lower the test temperature to −40° F. The minimum impact energy requirements of Ordnance Corps gun forging specifications, like those for reduction in area, are adjusted to the yield strength of the steel.

For example, the above-quoted specification calls for minimum individual values in multiple tests on individual forgings ranging from 42.5 ft-lb. transverse and 71.0 ft-lb. longitudinal for average yield strengths of 60,000 to 65,000 psi., down to 7.0 ft-lb. transverse and 15.0 ft-lb. longitudinal for yields of 180,000 to 185,000 psi. Specified values for an average yield strength of 150,000 psi. are:

	Transverse	Longitudinal
Single	18.0 ft-lb.	33.5 ft-lb.
Average of two	14.0	29.0
Average of three or four	11.0	26.5
Average of five or more	9.0	24.0
Minimum of multiple tests	7.0	22.0

The exact values stipulated in the specifications were established from correlated data assembled during and since World War II, including data from post mortem examination of serviceable as well as deliberately and accidentally failed components.

From the viewpoint of a materials engineer, the notched-bar impact test is used not so much to indicate whether or not a material will fail in service as it is to insure that the mode of failure, if it does occur, is not a catastrophic or brittle fracture.* If a gun is severely overstressed, as by an excessively large propellant charge, rupture of the gun tube by fissuring with no fragments broken off – that is, ductile failure – is far less dangerous to the artillerymen than if the tube were to burst into many fragments hurled in all directions – that is, by brittle failure.

There is also definite information, as remarked earlier, that at the same strength levels tough steels exhibit superior fatigue resistance. Since a brittle steel, by definition, is one that possesses little resistance to crack propagation, it is likely that a fatigue crack, once started, propagates through a brittle steel more readily (with less energy input) than through a tough steel. A tough steel is one which resists fracture, which absorbs energy through deformation rather than by cracking, and which requires the continual application of energy to extend the cracking process to final failure by fracturing.

Even though it has been long recognized that notched-bar impact tests are extremely useful in distinguishing between steels that are or are not subject to catastrophic or brittle fracture under conditions involving notches, shock loading, or low service temperatures, relatively little effort has been directed toward the use of Charpy or Izod test values by designers of structures. An atttempt to develop a quantitative approach of this nature has been made by the staff of the Watertown Arsenal Laboratories and has been published in the *S.A.E. Journal*, Vol. 59, March 1951, in an article entitled "Impact Tests Help Engineers Specify Steels". The method described in this paper has been used to establish the impact energy values contained in at least one Ordnance Corps Materials Specification. It seems to be satisfactory; at least no item bought under this specification has failed in service as a result of brittle fracture.

During the last decade a number of Ordnance Corps specifications for steels for components subjected to severe service applications have been prepared in cooperation with industry. Large quantities of such metal have been purchased under these specifications. The service performance of materiel manufactured from such steel (measuring up to certain impact tests to insure toughness) has been highly satisfactory. No service failure attributable to brittleness of the steel has been encountered. The specified temperature for the impact test in these specifications varies from −20° F. to −40° F., depending upon the anticipated use of the material.

*The following are some of the Ordnance Corps' specifications which employ the impact test as a measure of toughness:

MIL-S-10458 A (ORD), Steel Forgings for Cannon Tubes and Barrel Components

MIL-S-10026(ORD), Steel Castings (Centrifugal) for Gun Tubes

MIL-S-12253(ORD), Steel Castings for Muzzle Brakes

MIL-S-13326(ORD), Steel, Constructional, High Strength, Heat Treated (for Welded Structures)

MIL-S-10185(ORD), Steel Forgings for Breech Rings

MIL-S-10029(2)(ORD), Steel Castings for Breech Rings

MIL-S-11415 A (ORD), Steel, Parts, Ordnance

In addition to these are specifications for cast steel armor and wrought steel armor.

Machine Searching of Metallurgical Literature

By ALLEN KENT
ROBERT E. BOOTH
*and J. W. PERRY**

The ASM research project, only a year old, has already formulated a coding system adaptable to machine feed for various commercial computers and electronic selectors, and several thousand metallurgical abstracts have already been encoded and trial runs made on equipment constructed at Western Reserve University. (A14e)

I AM HERE to give a brief account of a project started by the American Society for Metals in 1955 to determine whether machinery could be used successfully in reclaiming metallurgical information from the great mass of existing periodical literature. But before attempting any detailed discussion, let us list the following questions:

1. What led to the establishment of this A.S.M. pilot research?
2. What are the immediate and long term goals?
3. What services can be expected from a mechanical searching system evolving from this project?
4. How must the current literature be converted into acceptable machine feed?
5. How would a sample question be searched in the anticipated reclamation service of the future?
6. Are suitable machines now available or reasonably to be anticipated?
7. What will be the fate of existing files of metallurgical information, for example, the ASM Review of Metal Literature?

Now I will try to give brief answers.

To the first – "What circumstances led up to the establishment of the research?" – I would remind you that the amazing growth of published metallurgical literature has gone hand in hand with the increase in American research. Raymond Ewell of the National Science Foundation found that such research expenditures have been increasing since 1920 at the rate of 10% per year. Continuing increase in the number of publications and intercompany reports accentuates the problem – already acute – of obtaining specific information from this record. This retrieval problem appears to increase geometrically, since it is determined not only by the size of the files, but also by the complexity of the subject matter.

The American Society for Metals recognized the need for bibliographic control more than a decade ago and took a first step in 1944 by

*Mr. Kent is associate director, Center for Documentation and Communication Research, School of Library Science, Western Reserve University, Cleveland; Mr. Booth is research associate, and Dr. Perry is director of the Center. This article is a shortened version of a paper read by Mr. Kent before a meeting of the Metals Div., Special Libraries Assoc., at the National Metal Congress and Exposition, Cleveland, Oct. 11, 1956.

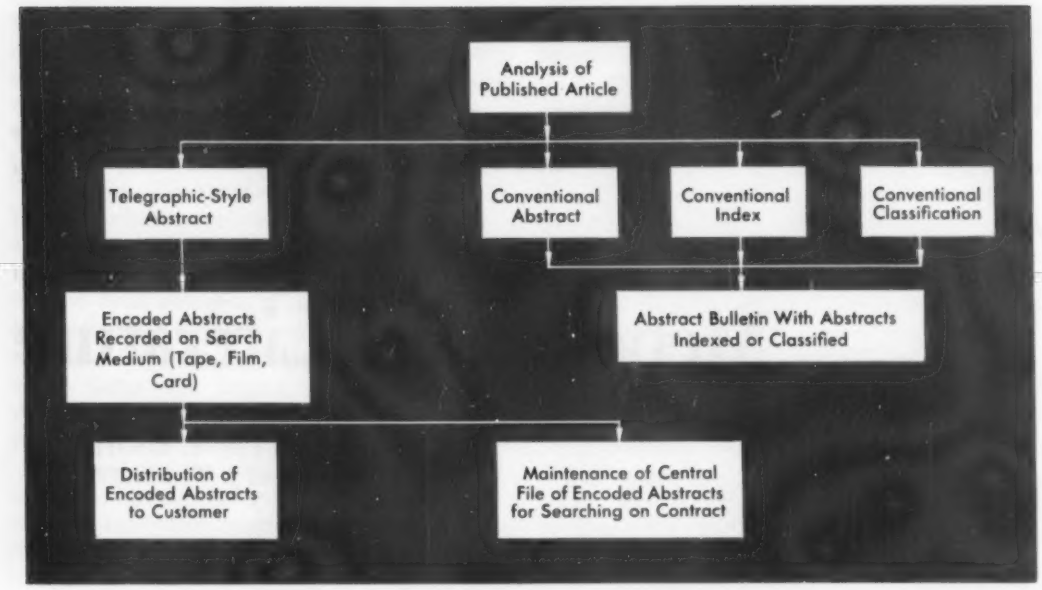

Analysis of Published Article
Telegraphic-Style Abstract
Conventional Abstract
Conventional Index
Conventional Classification
Encoded Abstracts Recorded on Search Medium (Tape, Film, Card)
Abstract Bulletin With Abstracts Indexed or Classified
Distribution of Encoded Abstracts to Customer
Maintenance of Central File of Encoded Abstracts for Searching on Contract

Fig. 1 – Services Available From Searching Systems

establishing the Review of Metal Literature. This is an abstracting service of the indicative rather than informative type, and it emphasizes promptness and completeness in specific areas of information. It is directed primarily toward the working metallurgist rather than the archivist or librarian.

A second step in the A.S.M. program was the compilation and publication by a hard-working committee in conjunction with the Special Libraries Assoc. of the "ASM-SLA Classification of Metallurgical Literature". This was in 1950. The classification by itself proved to be a most useful tool in the organization of literature resources, but a large further advantage is that it is specifically designed for use with a punched card system, hand operated.

While the Review of Metal Literature and the ASM-SLA Classification were designed with the needs of the individual metallurgist particularly in view, both immediately caught the attention of librarians and others who specialize in literature organization and searching, and the demand for something still more effective on a larger scale soon became evident. Needling by hand is limited to cards recording about 10,000 documents. Some other system was obviously necessary to handle the much larger collections that are certainly available in metallurgical literature. The Board of Trustees of the American Society for Metals, therefore, resolved that the Society should finance a pilot operation to study the application of computing-type equipment for this purpose.

It was also decided that the need for better methods of retrieving and correlating metallurgical literature was urgent, since the time is rapidly approaching when it would be cheaper to do a moderate-sized research job than to spend the time, effort and money for an adequate literature search. It was anticipated that such a system might become an important – and even essential – unit in the development of the educational and professional functions of the A.S.M. of the future.

Immediate and Long-Term Goals

The immediate purpose of the program set up by the A.S.M. at Western Reserve University is to test the feasibility of mechanized searching. A pilot-plant operation was obviously required, and the basis for such an operation had fortunately been provided by developments elsewhere, during the past ten years, both in equipment and in new methods for the indexing and coding of technical information preparatory to machine searching.

Highlights of the pilot operation might be summarized as follows:

A – About 25,000 important metallurgical papers in the current literature are being processed. (Pilot-plant tests are worthy of confidence

only if they are based on a reasonably large sample.)

B – Encoded "abstracts" of these papers are the basic materials. They are telegraphic in character and are particularly suitable for encoding for machine feed. It should be emphasized that preparation of encoded telegraphic-style abstracts is equivalent to providing a detailed subject index that can be searched by machine.

C – The above work is being done so that a wide range of commercial equipment can be used for searching, selecting and correlating.

D – Editing of abstracts and their encoding are based on techniques that combine the generalized and the specialized meaning of the terminology so as to express important aspects of subject matter. A code dictionary embracing more than 7000 frequently encountered scientific and technical terms was available and is being expanded to include metallurgical terminology.

E – Informative abstracts from *Metallurgical Abstracts* of the Institute of Metals, *Journal* of the Iron and Steel Institute, and *Chemical Abstracts* are the basic material. Eventually the encoded telegraphic-style abstracts may be prepared from the original publications.

F – Telegraphic-style abstracts require reviews by a person well versed in metallurgy to avoid mistakes from a misuse of terminology or misunderstanding of the subject.

G – The pilot-plant testing program may require as much as five years, the development phase being concentrated in the first part.

Eventual Services

Several services can be provided by a successful searching system, as shown in Fig. 1.

Let us consider that encoding for machine searching requires that metallurgical information shall first be analyzed. In the pilot operation, such analysis is done by the abstractor. However, it is quite feasible to work directly from original articles so that an analyst can prepare both an abstract in a conventional form ready for printing and also a telegraphic-style abstract ready for encoding for machine searching. Incidentally, the analyst could simultaneously indicate what index entries would be needed for the conventional subject indexes.)

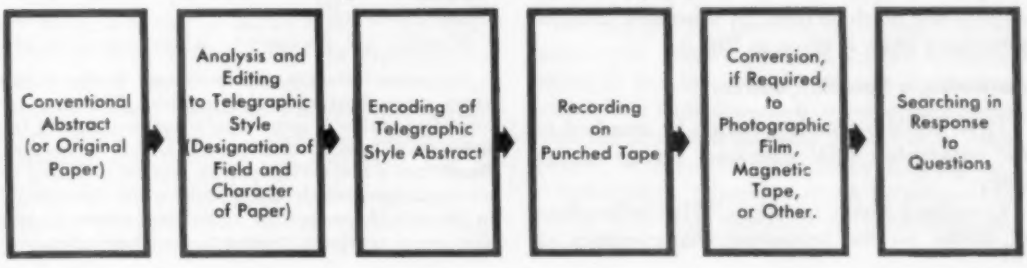
It thus appears that one eventual service would be a search and presentation of conventional abstracts to the customer. Another service would require a complete file of all the encoded abstracts at A.S.M. headquarters; questions from various organizations would be sent on a confidential basis to the searching service which would supply pertinent information either in the form of selected abstracts or copies of the original articles. Still another service would provide the special libraries of various organizations with files of abstracts or articles when a new metallurgical research program is being contemplated. Or a complete file of the encoded material, as produced by A.S.M., could be sold to those organizations having appropriate equipment so that searches could be performed on the company's own premises and coordinated with the company's own internal reports.

Machine Feed

As pointed out already, the first processing step is to convert existing abstracts into a telegraphic-style code. This is done in such a way that synonyms and alternate methods of phrasing the same idea in the original are rendered uniform and consistent – a necessity for machine searching.

Two aids have been provided the analyst who must perform this task: First, a set of rules has been worked out for editing abstracts in such a way as to eliminate the variations and complexities of English sentence structure. Second is the device of a "role indicator" which will show the relationship between the various ideas expressed in the search question – the "role" played by a specific word or term in the question.

Fig. 2 – Schematic of Processing Steps


Conventional Abstract (or Original Paper)
Analysis and Editing to Telegraphic Style (Designation of Field and Character of Paper)
Encoding of Telegraphic Style Abstract
Recording on Punched Tape
Conversion, if Required, to Photographic Film, Magnetic Tape, or Other.
Searching in Response to Questions

For example, codes have been devised to indicate whether a material mentioned in the question is a "starting material", a "material processed" or a "component". Other codes will tag an indexing term as to whether it is a process, a testing technique, or whether it influences a certain property. Semantically, such terms will automatically indicate whether "dog bites man" or "man bites dog".

Naturally, the ASM-SLA Classification of Metallurgical Literature is also used to locate the specific portion of the field in which each abstract falls – such as powder metallurgy, corrosion, and the like. In addition, the character of the papers to which the various abstracts pertain is indicated, such as "review", "theoretical", "basic research", or "descriptive". Experience has shown that such designation of specific field and general character of a paper enhances the effectiveness of search or selection with automatic or semi-automatic devices.

The next step in the process is to encode the individual terms and phrases of the telegraphic-style abstracts with the aid of a dictionary in which codes for specific terms express their meaning in such a way that related generic terms become available as reference points for defining and conducting searching operations. For example, the code for "induction furnace" will permit searches to be performed not only to "induction furnace", but also, more generically, to "electrical heating equipment" or to "electrical equipment" or to "heating equipment" or to "equipment". Also, the code for "tensile strength" will permit searches not only for "tensile strength", but also, more generically, to "mechanical property" or to "property".

The value of this will become increasingly evident as the file of encoded abstracts continues to expand in size. Suffice it to say, for now, that sufficient flexibility and capacity is being provided to cope with questions and large files beyond the capabilities of previous methods and systems.

The final step is to record the encoded abstract on punched paper, magnetic tape, or other appropriate machine feed. A schematic of these processing steps is given in Fig. 2.

Answering a Specific Question

How would a sample question be searched in the anticipated ASM searching service of the future?

Consider a simple question: "What is the effect of silicon on the tempering characteristics of steel?" which permits various important capabilities of the searching system to be illustrated.

It is common experience of reference librarians that information requests must be carefully considered as to *(a)* how carefully has the question been thought out and worded? *(b)* how extensive and exhaustive a search would the inquirer prefer?* and *(c)* is information related to the request of only indirect value to the questioner? – bearing in mind that the usefulness of related information tends to be greater when there is little or no direct information.

These considerations and related problems must be within the capabilities of the machine searching system. It must enable the operator to vary his strategy depending on whether he desires to include among the selected papers those that contain information not directly pertinent but of related interest.

First, let us consider the narrow interpretation. The question: "What is the effect of silicon on the tempering characteristics of steel?" would then be interpreted and analyzed for searching purposes as follows:

Identify all documents whose encoded abstracts are recorded as having the following characteristics:

I. Steel, only when it is either *(a)* a starting material, or *(b)* a material processed, or *(c)* when properties are given for it.

II. Silicon, only when it either *(a)* is a component, or *(b)* influences properties.

III. Designation in the encoded abstract as *(a)* a property given, or *(b)* a property influenced.

IV. Tempering, only when it is designated as a process. (This excludes mention of tempering as a function, for example, of a piece of equipment, but without actual use of the equipment being involved.)

Conducting a search of scope such as above specified might sometimes result in identifying insufficient information to satisfy the questioner. He might wish to review additional information that is closely related to his question though outside its scope when narrowly interpreted. Thus a broader interpretation and analysis might be set up as follows.

Identify all documents whose encoded ab-

*In some instances, the questioner wishes to see every paper bearing on his inquiry. The time required to review a large number of papers may be, however, a critical consideration in this connection. Sometimes a few review papers may be preferred to an exhaustive search, and provision has been made in the A.S.M. project for identifying review papers that are of pertinent interest to broad searches.

stracts are recorded as having the characteristics as given in I and II above plus

V. One or more of the following processes: tempering, annealing, spheroidizing, stress-relief, stabilizing anneal, graphitizing, malleabilizing, normalizing, austempering.

Each of the additional terms denoting processes is selected by consulting "tempering" in the "Reverse Code Dictionary", which brings together synonyms, near synonyms, and related terminology. The terms of our broadened search were actually obtained by consulting that portion of the semantic code dictionary which deals with "heat treatment". Two of the terms, *graphitizing* and *malleabilizing*, refer to the heat treatment of cast iron and not to steel, but this would lead to no difficulties since their inclusion in our question would yield no pertinent abstracts. In the reformulation of the search, we have therefore altered element IV to make the scope of search more generic in nature.

Finally, it should be understood that both formulations represented above may be searched simultaneously. As a matter of fact, Western Reserve University's Searching Selector is designed to search five independent questions at one time.

Available Machinery

Several types of machines can be used to process this type of coded material. These include "digital computers" and computer-like devices of the type exemplified by our own Searching Selector (demonstrated at the Metal Congress). These machines can be either specially programmed or specifically designed for the searches described. In addition, the Eastman Kodak "Minicard" equipment—with suitable electronic modifications—could perform the work.

Digital computing equipment is available from Sperry Rand (the series of machines known as "Univac"), International Business Machines (the "700" series), and others. Minicard equipment has been developed under Air Force sponsorship by the Eastman Kodak Co. in cooperation with the Magnavox Co. of Indianapolis. The IBM X-794, specifically designed for the experimental searching of encoded abstracts, it is believed could be made available within a reasonably short time. Western Reserve University's Searching Selector uses punched tape and is specifically designed to perform the logical operations needed for the effective searching of encoded abstracts. It is chacterized by very simple circuits, unusual capabilities for performing searches based on complex relationships. It is slow, but speed of operation could be increased by at least a factor of 10^3 by using vacuum tubes or transistors. Various other machines with somewhat lesser capabilities for performing the searching operations required are available from one or another manufacturer, and are too numerous to list here.

All in all, it may be concluded that electronic equipment, capable of performing this type of search is either now available or can be made available commercially at reasonable cost by the time the pilot operation nears its end. The computer department of General Electric Co. is undertaking development work on high-speed equipment of this type.

Fate of Existing Files

Assuming that the pilot-plant operation is sufficiently encouraging to warrant the establishment of a comprehensive encoding and searching service covering all contemporary metallurgical literature as it appears, the question will inevitably arise: "How can the old literature already analyzed by older systems be handled – how incorporate it into a comprehensive search?" Can the old material be economically analyzed and incorporated into the new system? Can a more-or-less automatic means be devised to translate one system into the other? Should the old system be kept running?

It is obvious that the cost of translation cannot exceed the cost of processing it as new material into the new system. Particular attention must be directed to the possibility of reprocessing the previous indexes or classifications, rather than reprocessing the documents themselves. This may give optimum benefits.

At any rate, in the extension of our code dictionary to include metallurgical terms, we are giving much attention to the existing ASM-SLA Classification so there will be a good linkage between the two systems.

Summary

Perhaps this last question is crossing a bridge before you come to it. The earlier questions posed in this article are closer to the task of establishing a mechanism to retrieve information from the mountainous mass of periodical information. A successful pilot plant will mean much to metallurgy. Obviously it can be adapted for use in all other branches of technology and science as well.

Taper Heating of Aluminum Extrusion Billets

*By A. J. MUELLER**

During extrusion, the temperature of aluminum billets increases by as much as 150° F. To obtain uniform properties of the extrusion, the billet should be preheated with a temperature differential by a special three-section induction coil. (F24, F21b; Al).

THE VERSATILITY and economic advantages of extrusion as a method of forming aluminum have caused a very rapid growth in its use for both military and domestic products. Superficially, the process appears to be rather simple. It consists of heating a billet, inserting it into the container in a hydraulic press and then applying sufficient pressure to force it through a die.

Unfortunately, maintenance of consistently high quality in aluminum alloy extrusions is difficult. The major problem is that aluminum, unlike copper and brass, actually gains heat during extrusion. The tail end of a billet may increase in temperature 125 to 150° F. during extrusion. Such an increase will not only change the response to heat treatment of the alloy but may also be sufficient to cause incipient fusion at the grain boundaries in some alloys. The only way to minimize the temperature variation is to reduce the extrusion speed, which of course will reduce the production rate. The increase in temperature can be attributed to two major factors:

1. The heat generated by internal friction within the container.

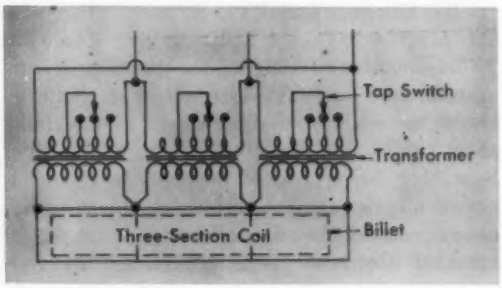
2. The heat generated by the intense shear effect at the restricted die opening.

In extruding a uniformly heated billet, a considerable amount of pressure is required in order to start the "break-through" of the extrusion. As the extrusion progresses, the power demand is lower and, unless the operator carefully controls the speed of the extrusion, the temperature will rapidly build up. The buildup in temperature at this stage is due to the heat generated by the intense shear effect in the restricted die opening; thus, the faster the extrusion speed the higher the extrusion temperature. Although a major portion of the heat is dissipated to the air either directly from the extrusion or through the container and die, its removal is generally not fast enough to prevent damage.

By extruding aluminum from uniformly heated billets without proper regulation of the extrusion speed to compensate for excessive temperature build-up, the following detrimental conditions can be produced:

1. *Die Pickup* — The first indication of excessive extrusion speed is revealed by a scored or broken surface on the extrusion. This condition is caused by the alloying of the die and

Fig. 1 — Electric Circuit Used to Control Power Input to Each Section of Induction Coil



*Sales Engineer, Detroit area, Magnethermic Corp., Youngstown, Ohio.

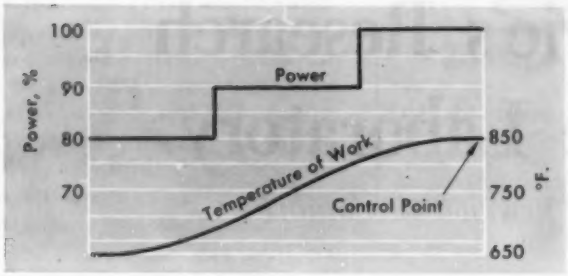


Fig. 2 – Temperature Differential Obtained With a Three-Section Induction Coil

the aluminum alloy when a critical temperature is exceeded.

2. *Hot Shortness* – All aluminum alloys tend to become brittle at a temperature near the melting point of their eutectic. This brittleness at the high temperature results in low strength of the extrusion as it emerges from the die and can cause transverse cracks on the extrusion surface.

3. *Melting of Eutectic* – A rise in temperature promotes the melting of eutectics which thereby cause intergranular cracks. Once these eutectics have melted, no heat treatment or subsequent operations can remove their harmful effects.

4. *Blistering* – After the eutectic melts, it could easily produce surface blisters. Such blisters could also be caused by the rapid expansion of entrapped gases which is caused by the high temperature.

5. *Improper Recrystallization* – Unless the pressure can be maintained constant during extrusion, grain size of the extrusion will vary from end to end. If the pressure is too low, the grain size will be coarse in the back end of the extrusion because of insufficient cold work or working at too high a temperature. If the original billet temperature is too low, heavier pressures will be exerted on the front end before the breakthrough and in subsequent heat treatment the severely strained grains will coarsen excessively.

These difficulties can be avoided if the billet is differentially heated with a marked thermal gradient from one end to the other. The hot end should be adjacent to the die face for ease in starting the extrusion, and the cooler end will absorb the heat of deformation. Such a thermal gradient can not be produced in either an air furnace or a conventional single-section induction coil, but a special three-section induction coil has been developed by the Magnethermic Corp. for such taper heating applications. The power input to each section is independently controlled through its own transformer and tap switch. Each transformer is fed power from one of the segments of a three-phase power source as indicated in Fig. 1.

The heat conductivity of aluminum is very high but if the billet is heated rapidly a smooth temperature gradient can be established. By adjusting the input in each section, the taper could be made as severe as necessary to meet the particular extrusion requirement. Common practice in the extrusion of aluminum is to use tapers up to about 200° F., as shown in Fig. 2.

A marked temperature variation exists on billets even after exposure to the air for a period of 30 min. One billet was taper heated to 950° F. at the front and 650° F. at the rear, and after 30 min. the temperatures dropped to 775 and 623° F. for the respective locations. A smaller billet heated to 990° F. at the front and 718° F. at the rear was checked 6 min. after it was removed from the coil and the temperature was 900° F. at the front and 750° F. at the back.

Since taper heating does produce a billet with the leading end heated to a high temperature to facilitate starting the extrusion and the remainder cool enough to compensate for the heat build-up in the container and die, it offers the following advantages:

1. The extruded surface is brighter because of the lower extrusion temperature.

2. Mechanical properties are more uniform.

3. Behavior in heat treatment is better.

4. Die life is longer because lower extrusion temperature results in less adherence of oxide particles to the die. The absence of these oxide particles produces a better surface on the extrusion. The dies need not be dressed as often; therefore, there is less downtime.

5. The operation can be started with the container 100° F. below working temperature. By having the temperature of the first few billets higher than the usual temperature, the container or die may be heated to the proper temperature by the extruding operation. After the container or die is up to heat, the billet heater can be immediately adjusted to produce billets with the standard production temperature. This feature will reduce downtime.

6. Because the extrusion temperature can be reduced by extruding taper-heated billets, the extruding speed can be maintained and consequently the production can definitely be increased because of the shorter cycle time.

General Electric's Research Metallographic Laboratory

*By J. B. NEWKIRK and A. S. HOLIK**

A group of eight microscopists and four diffraction experts, occupying an efficient layout of 3000 sq.ft., serve the 450 research workers in the General Electric Research Laboratory, examining and reporting on about 520 specimens monthly. (M20, M21, M22, M23)

RECENTLY, the General Electric Research Laboratory in Schenectady, N.Y. has enlarged its facilities for studying the structure of metals and ceramics. This move, involving a staff of 14 persons in its metallographic laboratory and nearly 3000 sq.ft. of floor area, emphasizes the importance of the study of structure to modern industrial research. The growing emphasis on fundamental science in metallurgical research requires a versatile metallographic laboratory. Furthermore, scientists working with nonmetals in a large modern laboratory often need the special facilities that a complete service laboratory devoted to the structure of solids can provide. Such a centralized laboratory offers increased general efficiency through economy of equipment, a wide range of skills in the personnel, and the counsel of specialists among them.

General Electric's Research Laboratory as a whole employs about 1400 persons, of whom about 450 are technical people carrying out individual research projects. These projects may range from the study of photons to the fabrication of a new alloy. To serve such a diversified organization the metallographic laboratory offers services in four major areas – optical microscopy, electron microscopy, X-ray diffraction and electron diffraction.

This four-group approach was first organized about three years ago and then was headed by the late A. H. Geisler. Before then, only optical metallography was available as a regular service. The new laboratory is part of the Alloy Studies Section of the Metallurgy and Ceramics Research Department, one of the four research departments of the General Electric Research Laboratory. Although most of the service work is metallurgical, the large number of jobs done for the other three departments (chemistry, electron physics and general physics) proves that this group is valuable to the entire laboratory and is playing an important role in the broad work of scientific research.

*Dr. Newkirk is research metallurgist in the Alloy Studies Section and Mr. Holik is in charge of the microscope service group, both of the Metallurgy and Ceramics Research Dept., General Electric Research Laboratory, Schenectady, N.Y.

Personnel

The optical microscopists make up the largest group in the unit, having six operators, two of them women. Working closely with them are two electron microscopists. These eight people share the same specimen preparation area and optical microscopes. Their average age is 27 years. Two are college graduates and the others have had high school plus technical school training or a few years of college. Most have gained their metallographic experience on the job in this laboratory.

The diffraction group is composed of two subunits, X-ray diffraction and electron diffraction. At present the group consists of four operators, three of them women. Three are college graduates.

The turnover has been fewer than two per year, and those leaving the group usually become personal assistants for scientists within the laboratory. Replacements are usually former general laboratory assistants, although some come straight from school.

Several methods are provided by which a metallographer can continue his training while on the job. Both Union College in Schenectady and Rensselaer Polytechnic Institute in nearby Troy offer evening courses which are available to employees under company sponsorship. Also, General Electric provides many courses in its own training program, together with technical seminars for laboratory assistants and technicians.

Table I – Work Load (Monthly Averages)

Sub-Unit	Jobs Completed	Photographs Reported	Photographs Analyzed
Optical microscopy	117 to 143	470	—
Electron microscopy	5 to 9	41	—
X-ray diffraction	36 to 52	80	56
Electron diffraction	3 to 9	27	7

Layout of Laboratories

The floor plan of the microscopy area is shown in Fig. 1. In laying it out, a special effort was made to put consecutive operations close together and to isolate areas where critical steps are to be taken in the preparation of specimens.

For example, the electron microscopists have a darkenable specimen preparation room of their own where replicas of polished and etched specimens may be made in draft-free air; the electron microscope itself stands alone in its own air-conditioned room. The room for rough grinding is completely separated from the polishing areas; a wall also separates the coarse polishing and the fine polishing wheels, so air-borne grit has little chance to settle on the fine polishing wheels.

In the etching room the sink, fluid services (hydrogen, nitrogen, oxygen, air, steam, distilled water, hot de-ionized water and cold water) and special electrical outlets are located close to each other for maximum operating convenience. Most hot and cold water faucets are controlled by foot pedals, leaving the hands free. An emergency shower is provided in the event of an accident with the chemicals.

Special techniques, such as electrolytic polishing and vacuum cathodic etching, are performed in an alcove off the main etching room. A constant flow of air from adjacent areas into the etching room is provided by a powerful draft through hoods near the sinks; thus, corrosive vapors cannot reach the major optical equipment, and annoying odors are quickly drawn away. An inexpensive table microscope is provided in the etching area so a specimen may be examined during preparation without requiring the operator to go to the main microscope bench, which is well-removed from the etching sinks.

Two large metallographs are kept in each of two completely separate semidarkenable rooms. A macrocamera is also located in one of these rooms. Just outside is a bench with four table microscopes for examining specimens when no photograph is required.

The photographic darkroom consists of two separate areas, one where film is processed and one for printing and enlarging. Reports are finally assembled in the main personnel seating room, which runs practically the entire length of the area (Fig. 2).

The plan of the diffraction area, which is completely separated from the microscopy area, is shown in Fig. 3. The X-ray diffractometers are kept in a room which is separated by a wall from the personnel area. The X-ray units with film cameras are kept in a room that also serves as a darkroom (Fig. 4). Films and diffractometer charts are analyzed in the shielded personnel seating area. The electron diffraction instrument is kept in a darkenable room of its own which also serves as a darkroom for the electron diffraction photographic work. While the major equipment is shown in Fig. 3, it omits the various standard types of diffraction cameras and film analyzers.

Operation

The work load is such that it takes about a week to report on an average job. Average monthly work loads are shown in Table I for jobs requiring standard techniques. This does not include time spent in developing new methods.

A service job in microscopy originates when a scientist submits a specimen accompanied by a standard work request card identifying the specimen, giving its composition and heat treatment, a diagram of the section to be examined and an indication of the information sought. Standard jobs are discussed with the metallographer in charge of accepting work. All jobs are recorded in a log book with their identifying numbers.

The specimens and cards are next placed on a central table where the members of the group can select the work which they wish to do. We believe that voluntary selection gives better over-all results than specific assignments. The

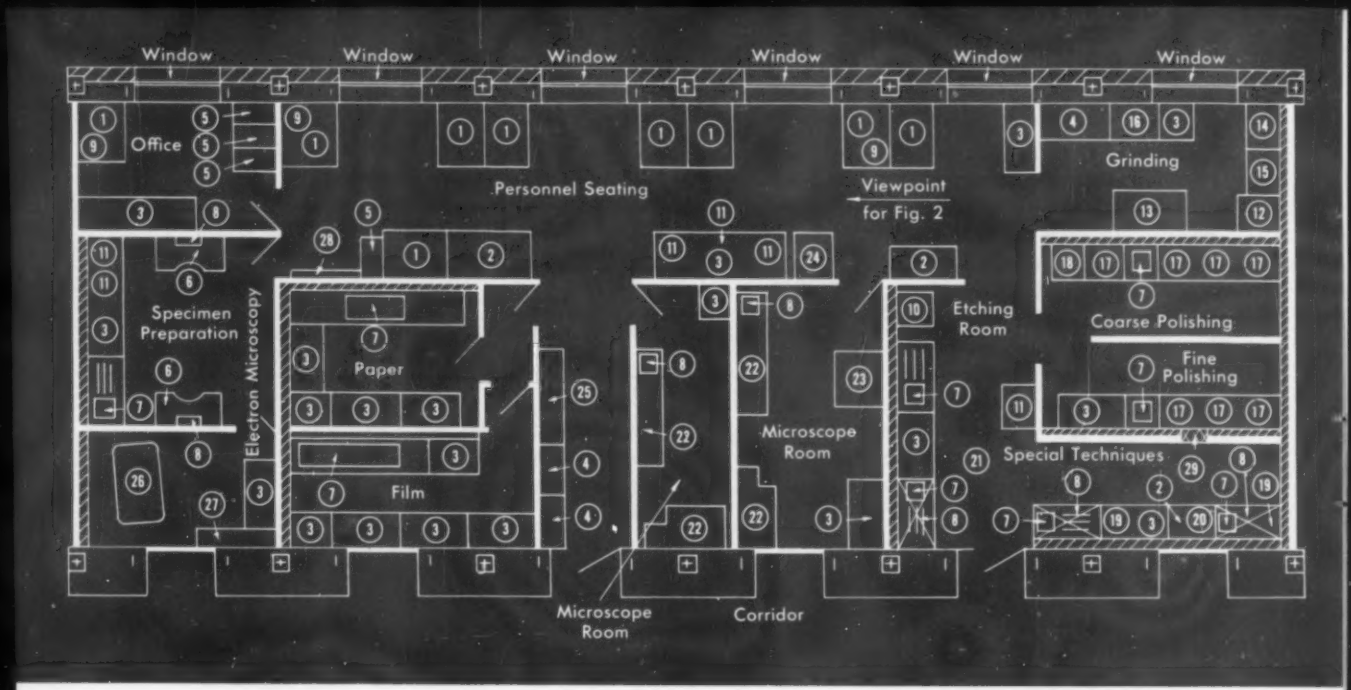


Fig. 1 — The Microscopy Area Is Laid Out to Provide a Minimum of Interference Among Operating Personnel, Yet Keep Areas of Sequential Operations Close Together

1. *Desk*
2. *Table*
3. *Bench-cabinet*
4. *Storage or instrument cabinet*
5. *File cabinet*
6. *Microscope table*
7. *Sink*
8. *Hood*
9. *Telephone*
10. *Refrigerator*
11. *Table microscope*
12. *Cut-off machine*
13. *Belt grinder*
14. *Mounting press*
15. *Grinding lap*
16. *Manual grinding papers*
17. *Manual polishing wheel*
18. *Automatic mechanical polishing unit*
19. *Electropolishing unit*
20. *Cathodic etching unit*
21. *Safety shower*
22. *Research metallograph*
23. *Macrocamera*
24. *Microhardness tester*
25. *Rotary print dryer*
26. *Electron microscope*
27. *Room air conditioner*
28. *Blackboard*
29. *Escape hatch*
30. *G.E. XRD-1 (X-ray generator)*
31. *G.E. XRD-3 (X-ray generator)*
32. *G.E. XRD-4 (X-ray generator)*
33. *X-ray spectrometer*
34. *Spectrometer recorder*
35. *Automatic pole figure recorder*
36. *High-temperature camera with vacuum pump*
37. *Metal evaporating unit*
38. *Electron diffraction unit*

operator is then responsible for all subsequent metallographic steps from sectioning and mounting the specimen to assembling the final photographs and reporting to the scientist who submitted the job.

Reports from the optical and electron microscopists are checked only by the group leader. The specimens, negatives, and a copy of each report are stored for five years; scientists who wish to keep their specimens or negatives longer may withdraw them for their own files.

Procedures in the diffraction laboratory are

Fig. 2 — Seating Area Is Well Lighted and Centrally Located. Appearing in this photograph are Mrs. Jean Tomlinson, D. E. Broecker, R. E. Skoda, Miss Dorothy Kontoleon, W. A. Roman and A. E. Wituszynski

about the same, although a given job may be done by more than one person. Frequently X-ray photographs are made by one person and analyzed by another. The report is then jointly signed and checked by the general metallographic supervisor before it is sent out.

Growth Through Individual Development

Most of the work on solid structures is done with standard metallographic techniques, but new and specialized ones – occasionally developed in cooperation with individual researchers – are added to the available services from time to time.

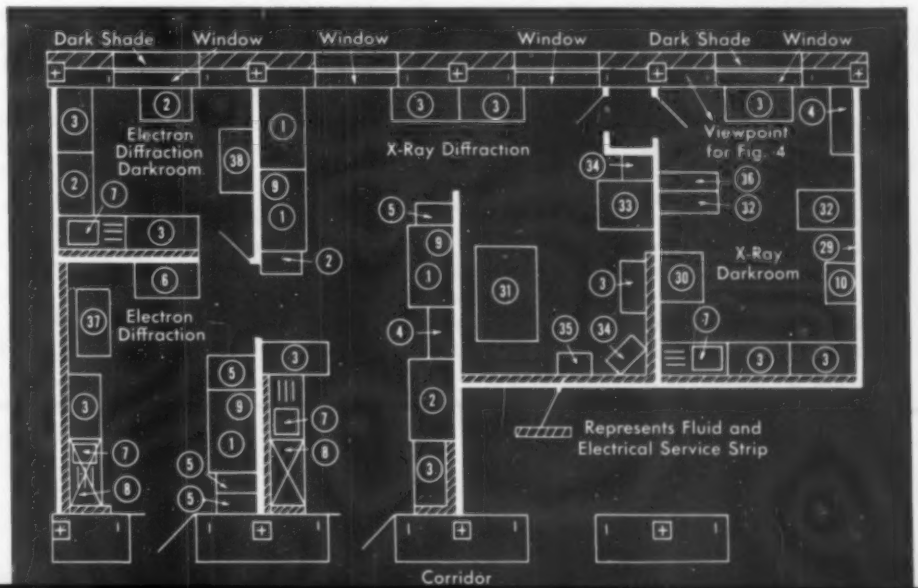
Besides performing the standard operations, each metallographer is encouraged to devote about 10% of his time to the development of an already known but more highly specialized technique. For example, one may specialize in interference and phase contrast microscopy, another in etching by ionic bombardment, and another in autoradiographic techniques. This specialization lends great breadth to the group's ability, although no single person need master *all* of the special techniques.

Personnel keep abreast of the times through weekly one-hour discussions of subjects pertaining to their work. For instance, scientists whose work involves much metallography are invited to explain the broad objectives of their project and to point out specifically the part which metallography plays. Specialists outside the company are occasionally invited to address the group on a subject relating to metallography. For example, a representative of Eastman Kodak Co. recently talked about the chemistry of the photographic process, climaxing a seminar in which the metallographers, each week for four weeks, discussed the photographic process as presented by a well-known text. Occasionally, an appropriate motion picture is shown.

Fig. 4 – Film Diffraction Work Is Performed in a Darkroom Which Also Contains the X-Ray Generators. W. G. Martin views an X-ray film as R. Lewinski (foreground) works with the high-temperature X-ray camera

Since its beginning more than 20 years ago, the group of metallographic specialists at General Electric Research Laboratory has grown steadily because it has proved to be a very real aid to the research in progress. By growing with its parent organization, this group has provided an efficient service to the laboratory and at the same time has proved to be an effective training ground for budding laboratory technicians. The quality and technical excellence of the work is sufficiently proved, we think, by the fact that our members have won a total of five "Best in Class" blue ribbon awards and six "Honorable Mentions" in the ⊕ Metallographic Exhibits in 1955 and 1956. ⊕

Fig. 3 – The X-Ray and Electron Diffraction Area Requires 1056 Sq.Ft. to House Equipment and Four Technicians to Operate It



Radiation's Influence in Evolution

The Editor's Query

Commissioner Willard F. Libby
A.E.C., Washington

I enclose two items from *Metal Progress's* pages on "The Atomic Age". One from the October 1955 issue quotes from your address on "Radioactive Fallout" and brings out the point that dwellers in low altitudes receive 0.115 roentgen per year from cosmic and terrestrial radiations. Dwellers in high altitudes over granitic rocks get more from both sources, the total being about 0.160. Worse, the average civilized youth gets about 0.100 r. per year from medical and dental X-rays and luminous wrist watches. Finally, bomb fall-out subjects him to an additional 0.02 r. per year.

Thus the average American is now receiving continuously about twice the amount of cosmic, gamma and X-radiation which his grandfathers endured. The eminent geneticists reporting to the National Academy of Science (as quoted in *Metal Progress* for September 1956) say that such radiations cause occasional mutations in human genes, that most mutations in reproductive cells are harmful, and can be exterminated in future generations only through tragedy.

Even so, I am wondering whether such radiation-induced mutations may not produce an occasional Lincoln or Newton (along with a Stalin or a Hitler). Another question persists in my mind, and that has to do with the relative amount of radiation which existed on this planet when *homo sapiens* first appeared, maybe a hundred million years ago — or was it only one million? In other words, is it a roughly correct assumption to say that mankind did not appear until the general level of radiation had decayed to a point where it was possible for him not only to survive, but also to evolve? Doubtless a reasonably good estimate could be given about the average natural radiation existing, say, on the plains of Mesopotamia, the traditional cradle of the human race, at the time he appeared. What is it now? Is it a larger difference than exists, say, at sea level and at Leadville, Colo.?

Finally, are there any accurate data about life expectancy of races of men such as the Tibetans or the Peruvians, who presumably have been living at a high elevation for hundreds or thousands of generations, in comparison with aborigines in some isolated land mass near sea level?

It seems to me that this might be a very practicable way of avoiding some of the long extrapolations which the geneticists now apparently have to make in translating their experimentation and observations on animals to what we might expect in the human race several thousand years from now.

E. E. THUM

The Doctor's Reply

Dear Mr. Thum:

Your letter to Commissioner Willard F. Libby has been referred to me for reply.

In regard to your question about changes in the general level of radiation in man's environment during the development of the race, these have been too small to shed any light on the level of radiation which might be hazardous to the race. About half of the natural radiation background is due to cosmic radiation and about half is due to the occurrence of radioactive materials in the surface of the earth. We have no reason to think that the intensity of *cosmic* radiation would have changed significantly throughout the history of the earth. As to terrestrial radiation, the average radioactivity of the other short-lived radioactive materials in the surface of the earth is in equilibrium with the activity of the isotopes of uranium and thorium from which they are descended. Since the half-lives of these isotopes of uranium and thorium range from 1 to 10 billions of years, the decrease during the development of the human race would be much less than 50%. Further, it is estimated that less than one tenth of the genetic mutations naturally appearing in man are due to radiation.

In view of these considerations, one cannot draw any conclusions as to the part played by radiation in the evolution of man or as to his ability to live in an environment of higher radiation levels.

Somewhat similar considerations apply to any comparison between peoples living at different altitudes. For example, while persons living at an altitude of one mile are subjected to levels of cosmic radiation twice as high as at sea level, this might account for an expected increase in mutation rate of about 5%. One would expect that other environmental differences would have a much greater effect on such factors as health and life expentancy than would this small increase in genetic mutations. At the present stage of our knowledge, we believe that it would be impossible to evaluate individual environmental factors with sufficient precision to throw any light on the problems raised by the National Academy of Science study.

There is also the possibility of obtaining some information from known stable populations living in areas in which the radiation is about ten times that in nearby locations. However, the populations studied may differ sufficiently in other factors, both environmental and inherent, to make it difficult to evaluate the effects of radiation with accuracy.

CHARLES L. DUNHAM, M. D.
Director, Division of Biology and Medicine

Service Life of Metal Belts in Copper Brazing Furnaces

By FRED L. HOOPER*

Woven wire belts used in copper brazing furnaces last longer if tension is reduced, speed is increased and the belt is reversed periodically. (S21, W12, W29; SS, Ni)

SELECTION of the best alloy and best design for the woven wire belts used in metal treating furnaces is extremely difficult because of the complete lack of reliable information on engineering properties of metals in the range from 1800 to 2100° F. The problem is complicated even more by the conflicting information published by various belt manufacturers concerning safe working stresses and the service life to be expected from different alloys.

There should be a general relationship between tension, temperature and service life of the belts, but a field study of hundreds of furnaces operating in the range from 1800 to 2100° F. indicated that the relationship differed for each kind of application. In copper brazing furnaces, for example, the service life of a belt would be entirely different from that in a continuous furnace annealing stainless steel components. It appears that sound predictions of service life of belts must be based on an engineering analysis of experience in similar applications.

More woven wire belts are used in copper brazing furnaces than in any other high-temperature metal treating operation so we decided to investigate such installations first. The results of our study have shown that belt life can be predicted and have indicated how relatively small changes in operating variables can affect service life appreciably.

At least six different alloys have been used in copper brazing furnaces, and the first problem was to determine which alloy, or alloys, provided the most economical service. We limited our study to furnaces operating at 2050° F., but because of variations in belt loading, size of furnaces, length of heating chambers, atmospheres and belt maintenance practice in the plants that provided us with data, it was difficult to evaluate the performance of the different alloys. The only alternate was to test all of these alloys under identical conditions. A belt was made with seven equal sections, each a different alloy, and it was installed in a copper brazing furnace. Stand-by sections were provided to replace sections that failed so that the maximum life of each individual section could be determined.

The lowest priced alloys were Types 310 and 314 – 25% Cr, 20% Ni and 1.40 and 2.41% Si, respectively. The Type 314 section lasted much longer than the low-silicon Type 310, probably because of its superior resistance to oxidation. Only two other alloys gave superior life; a 19%

*Executive Vice-President, Cambridge Wire Cloth Co., Cambridge, Md.

Cr, 35% Ni alloy which cost about 25% more than Type 314 lasted 55% longer, and an 80% Cr, 20% Ni alloy which cost twice as much as Type 314 also had 55% longer life.

The 19 Cr, 35 Ni alloy was first used in belts for copper brazing because of its exceptional resistance to green-rot attack. In service, a black tightly adherent oxide is formed which protects the metal against further attack.

Although each alloy was tested under identical conditions, we realized that there was a possibility that their behavior might be different in other furnaces. To check our findings, we repeated the experiment in two other plants, each with a copper brazing furnace of different manufacture. The atmosphere in all furnaces was exothermic gas. In each test, the best three alloys were the same and the relationship between belt cost and service life remained constant.

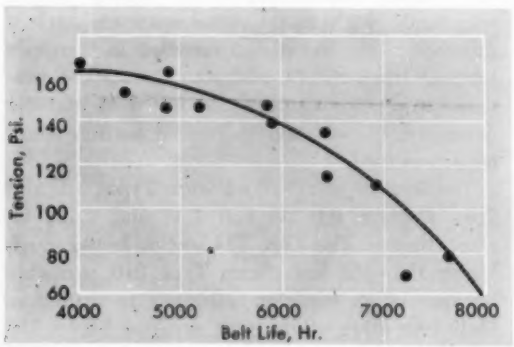
Service life of the test belts in one of the furnaces was 8000 hr. and in another, 4000 hr. The belt design, furnace temperature, belt speed and atmosphere were identical but there was a difference in the tension applied to drive the belt. The three tests were not sufficient to determine the exact relationship between belt tension and service life so we re-analyzed the data from 72 of our installations in copper brazing furnaces. From these, we selected 12 that were similar in all variables except tension applied to the belt.

Tension on the belt at the exit end of the heating chamber (where the belt reaches its maximum temperature) may be computed from the formula:

$$T = (W_b + W_1)\,(f \times L)$$

where W_b is the weight of the belt in pounds per lineal foot; W_1 is the weight of the load in pounds per lineal foot; f, the coefficient of friction, which is 0.55 at 2050° F.; and L, the distance from center of the drive pulley to the exit end of the heating chamber.

Fig. 1 – Effect of Belt Tension on Service Life in Copper Brazing Furnaces



The relationship between service life and tension is shown in Fig. 1.* The importance of operating belts at minimum tension is obvious. By increasing the tension from 140 to 160 psi. belt life is shortened 1000 hr. At higher loads, the effect of an increase in tension on service life is even more severe.

Minimum tension can be obtained by driving the belt from the charging end of the furnace so that there is no tension on the belt as it leaves the charge end pulley. It is customary to drive belts operating at low temperatures from the discharge end of the furnace, but in the range of temperatures used in copper brazing, it is imperative that the drive be at the charging end to minimize tension.

Belt speed affects the tension and it has often been erroneously assumed that an increase in the speed of the belt will shorten the service life. However, Fig. 2, which is based on the installations studied, indicates that with all other conditions constant, service life of the belt is increased when the speed of the belt is increased. For example, if the rate of speed of one belt is twice that of another, the service life of the faster belt is more than double that of the slower. This indicates how the combination of temperature and furnace atmosphere affects belt life and suggests the advisability of moving the belt through the heating chamber as rapidly as possible. The rate of speed for a belt is controlled

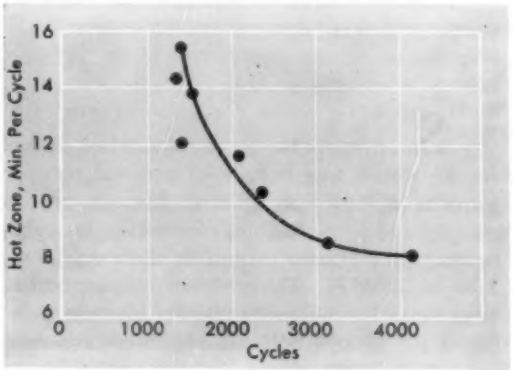


Fig. 2 – Relationship Between Belt Speed and Service Life

*T is converted to pounds per square inch by dividing the value for T in pounds by the total cross-sectional area of the belt in square inches.

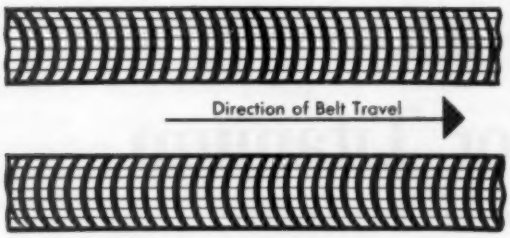


Fig. 3 — Kinds of Camber Developed by Woven Wire Belts in Service. Convex camber is shown in upper diagram, concave in lower

by the length of time required to complete the copper brazing process, and while this range is limited, it is important to move the belt as fast as possible.

Copper brazing belts run at a very slow speed and quite often the movement is in short jerks instead of a smooth motion. In effect, between each pause or hesitation, the belt stops and it is necessary to apply a new starting tension to move it to the next notch. By increasing the speed of the belt, this intermittent movement is minimized and the resulting smoother motion produces less actual driving tension.

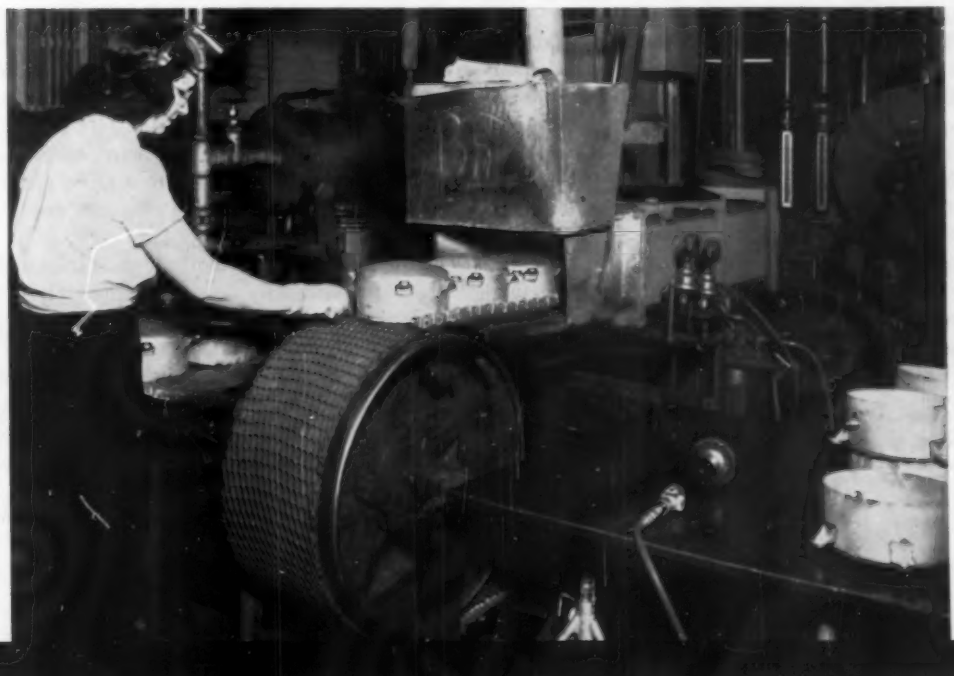
Belts used in copper brazing furnaces usually develop either a convex or concave camber as shown in Fig. 3. Sometimes this condition is worsened by one extremity of the camber pulling ahead of the other. It may result from a columning effect, drafts in the cooling chamber, uneven loading, uneven driving tension or a combination of these conditions. As the amount of camber increases, free hinging of the individual belt units passing over the end pulleys is hindered and flexure of the individual belt units occurs. This cambering effect may be minimized by removing the belt from the furnace at intervals, turning it around and running it in a direction opposite to that in which the camber was produced. When this is done, the individual belt units gradually straighten themselves and finally assume the opposite camber. An ideal time for this reversing procedure would be when the camber reaches a half-inch depth, or when one side of the belt pulls ahead that same distance. It is not always possible in a production plant to make the reversal regularly at such intervals and in such instances the next best procedure is to make the reversal whenever the furnace is shut down. However, periodic reversal is of utmost importance since our studies showed that those plants that reversed their belts obtained an average of 50% longer belt life. Belts should not, however, be reversed after they become rigid and embrittled from long service.

To summarize, our studies have indicated three ways to increase service life of woven belts in copper brazing furnaces other than alloy selection and belt design. They are:

1. Decrease belt tension.
2. Increase belt speed.
3. Reverse the belt periodically.

These operating practices will also affect service life of belts used in other metal treating operations, but we do not yet know exactly how much service life can be improved in each application. Similar analyses of other metal treating processes are now under way.

Fig. 4 — Copper Brazing Installation at Metal Electric Processing Plant, Toledo, Ohio



Molybdenum as an Alloy Addition for Titanium

*By HAROLD MARGOLIN**

A 7% Al, 3% Mo alloy has superior strength-weight properties at elevated temperatures. Molybdenum also has favorable influence on hardenability and oxidation resistance. It seems possible that, with its help, a useful age-hardenable alloy can be developed. (Q general, 2-10; Ti, *Mo*)

MANY SERIOUS PROBLEMS which dimmed the early high promise of the metal titanium have been solved and the way now appears open for its wide application in jet engines and air frames. The rate at which its use will grow will depend largely on how readily and how well it can meet the requirements in competition with other metals and alloys.

Commercially pure titanium has a relatively low density, is fairly strong and highly corrosion resistant. However, to realize its full potential, it is necessary to alloy it. Unlike aluminum, titanium atoms rearrange themselves (transform) on heating or cooling through a critical temperature, 1620° F. The low-temperature arrangement is known as alpha titanium and the high-temperature form as beta titanium.

The beta phase existing in hot titanium can be retained at room temperature by adding sufficient amounts of molybdenum, vanadium, columbium, iron, chromium or manganese – the "beta stabilizers". The retained beta is not stable and will revert (at least in part) to the alpha modification on reheating – a characteristic of all alloys containing retained beta, regardless of what alloying element is used. This is not altogether undesirable, because after a proper age hardening heat treatment, strength can be increased 50,000 to 80,000 psi. over the value for as-quenched alloys, reaching as much as 220,000 psi. ultimate strength while maintaining a fair amount of ductility. However, in order to retain beta on water quenching, from 5 to 15% of common alloy addition is required. By using two-phase alpha-beta alloys, beta can be retained with smaller amounts of beta stabilizer.

Commercial alloys are now either all alpha or alpha-beta. The latter have received wider attention, principally because of their higher strengths. A list of the American commercial alloys is shown in Table I.

It will be noted that the beta stabilizers now being used commercially, with and without aluminum, are iron, chromium, manganese, molybdenum and vanadium. Two of the commercial alloys contain molybdenum.

There are some limitations on the way in which some of these alloying elements can be put together. Iron and chromium used singly or together (without another element) will retain a beta phase which will decompose into alpha and a brittle compound; the decomposed alloy has poor ductility.

Alloys containing manganese alone or with aluminum could theoretically form an intermetallic compound but (probably because of an extremely sluggish decomposition) no such compound has been reported. Because the phase diagrams of titanium with iron, chromium and manganese indicate that the beta phase decomposes by eutectoid reaction into alpha and compound, these three alloying elements are known as "eutectoid formers".

Molybdenum (and similarly vanadium, columbium and tantalum) dissolves completely in beta titanium; they therefore are known as "beta isomorphous elements". Because they do not form intermetallic compounds, they would be desirable for alloys used at high temperatures.

The above list shows that six of the nine commercial alpha-beta alloys contain aluminum,

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present, for the most part, in the alpha phase. Aluminum enhances the high-temperature strength and creep properties quite considerably, but is most frequently used with a beta stabilizer, because at room and intermediate temperatures the strength of binary Ti-Al alloys is rather low.

It was pointed out earlier that decomposition of beta could raise the strength by age hardening or embrittle by compound formation. Another way in which tensile properties can be changed, somewhat deleteriously, is by precipitation of alpha from the beta during a stay at elevated temperatures, below its original solution heat treatment. One way to counteract this is to reduce the amount of beta in the alloy, thus proportionately reducing the influence of any alpha which may precipitate.

Four empirical rules have thus evolved for the design of alpha-beta alloys for use at elevated temperature:

1. In order to avoid formation of compounds, the alloys should not contain Fe or Cr (alone or together) without offsetting additions of other elements such as Mo, V or Mn. Compound formation can be avoided by the use of Mo, V, Cb, Ta or Mn without Fe or Cr.
2. The alloys should contain Al, which is the most potent contributor to high-temperature strength.
3. The alpha phase should be the major phase in order to limit the unwanted changes in the beta phase.
4. Proper beta stabilizer elements should be present to provide the strength necessary at room and intermediate temperature.

The above rules were followed in the development of the 6% Al, 4% V alloy, combining the advantages of aluminum with a beta isomorphous element. It has been widely accepted by users of alloyed titanium mill products. It is stable and the properties do not undergo appreciable change on prolonged exposure to elevated temperatures. However, its creep strength at elevated temperatures is no better than binary Ti-Al alloys, as shown in Fig. 1 and 2.

Table I – Commercial Titanium Alloys

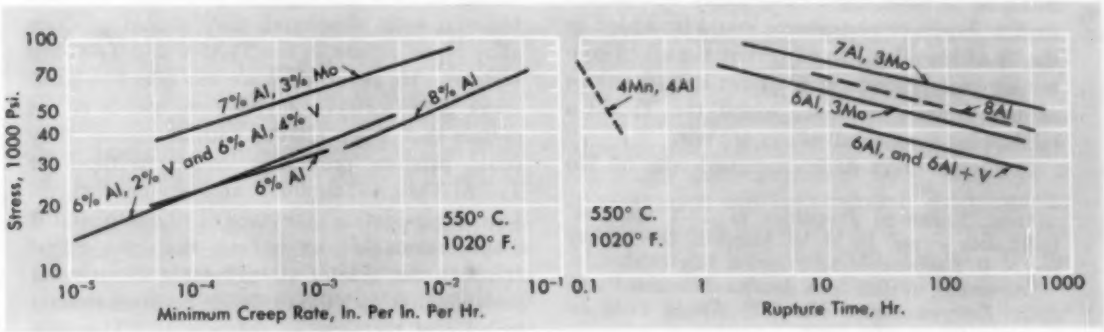
Designation	Additions	Lippert Code*
Alpha-beta alloys		
Ti-140A	2 Cr, 2 Fe, 2 Mo	T96035
Ti-155A	5 Al, 1.4 Cr, 1.3 Fe, 1.4 Mo	T94520
MST5Cr-3Al	5 Cr, 3 Al	T753XX
MST6Al-4V	6 Al, 4 V	T34620
C130AM	4 Al, 4 Mn	T644XX
C110M	8 Mn	T680XX
RS110	3.5 Cr, 1.5 Fe	T950XX
RS140	5 Al, 2.75 Cr, 1.25 Fe	T945XX
RS110B	3 Mn, 1.5 Al	T632XX
Alpha alloy		
A110AT	5 Al, 2.5 Sn	T008XX

*See *Metal Progress* Data Sheet, p. 112-B, January 1957. The last two digits denote oxygen plus twice nitrogen contents.

New Ti-Al-Mo Alloy

Studies at Armour Research Foundation have shown that if molybdenum, also a beta isomorphous element, is used instead of vanadium, creep properties are considerably improved. For example, at 1020° F. (Fig. 1) a stress of approximately 20,000 psi. produces a creep rate of 10^{-4} in. per in. per hr. in Ti-6 Al and Ti-6 Al-4 V, whereas 40,000 psi. is required to produce the same creep rate in the Ti-7 Al-3 Mo alloy. Figure 2 shows that a stress of 30,000 psi, at 1020° F.

Fig. 1 and 2 – Minimum Creep Rate and Rupture Time at 1020° F. for Ti-Al, Ti-Al-V and Ti-Al-Mo Alloys. Data from Armour Research Foundation's report to Wright Air Development Center, WADC T.R. 54-278. Line for 4 Mn, 4 Al is a possible extrapolation of data from Rem-Cru Titanium, Inc.



will produce rupture in both Ti-6 Al and Ti-6 Al-4 V alloys in about 200 hr., but the same stress does not break the Ti-7 Al-3 Mo alloy after 1000 hr. Better creep and rupture properties can be had in the 7 Al-3 Mo than in an 8% Al alloy.

A precipitation hardening stainless steel, 17-7 PH, is quite frequently compared to titanium as a competitor for elevated-temperature aircraft applications.* A comparison of the strength-weight ratios over a range of temperatures is given in Fig. 3. Whereas 17-7 PH, Ti-8 Mn and Ti-6 Al-4 V appear quite similar up to 800° F., the 7 Al-3 Mo alloy is considerably better.

Sheet 0.060 in. thick has been produced from the Ti-7 Al-3 Mo alloy. Investigators at Armour Research Foundation found that the sheet is brittle as-welded and would require post-weld heat treatment to improve ductility. In view of the difficulties encountered in forming Ti-6 Al-4 V sheet, it is quite probable that the Ti-7 Al-3 Mo sheet would probably be still more intractable because of its higher aluminum content. Therefore the Ti-Al-Mo alloy, or some modification, is more likely to serve as a forging alloy. However, some of the same features which recommend the Ti-Al-Mo system for high-temperature application may bring about some uses in sheet, as will be discussed later under the section on hardenability.

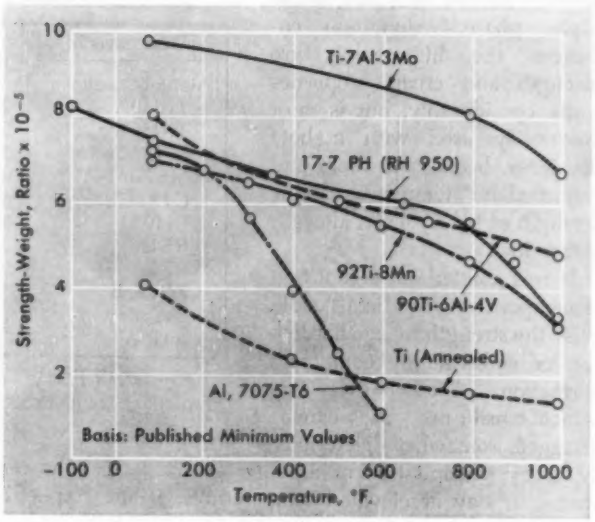


Fig. 3 — Strength-Weight Comparison of Several Alloys Usable for Aircraft. (Adapted from Metal Progress *Data Sheet, July 1956, p. 96-B.) Short-time tensile tests (minimum values) are used for all alloys except titanium alloy containing 7% Al and 3% Mo. Data from Armour Research Foundation Report to Wright Field, WADC T.R. 54-278. The new alloy was heated at 1610° F. for 24 hr., air cooled, reheated at 1025° F. for 24 hr., air cooled. This treatment probably does not produce "minimum" results*

Modification of the basic Ti-7 Al-3 Mo prototype has just been mentioned. Additions of tin and zirconium are beneficial.† It is certain that other improvements can be made as the alloy becomes better known. Some leads may come from investigations of the Ti-Al-Cu system, whose alloys are of the alpha-plus-compound type. The problem with them is to establish the compound in a controlled dispersion. If this can be done, then conceivably an element such as boron or phosphorus could be added to the Ti-Al-Mo alloy. In any event, the alloys containing molybdenum would have the advantage of being heat treatable, which the Ti-Al-Cu (alpha-plus-compound) alloys are not.

If the use of 7% Al is continued with 3% Mo it will be necessary to keep the total oxygen and nitrogen low, since these interstitial atoms favor the formation of an intermetallic compound, primarily associated with the aluminum addition. The amount of compound increases with the size of the aluminum addition and the oxygen content, and much work is currently being done on binary and ternary Ti-Al alloys to determine the circumstances under which compound forms. Oxygen and nitrogen can be kept low if present-day high-purity sponge is used. It may also turn out that, as an additional safeguard, only 6% Al will be added instead of 7%.

Columbium and tantalum were mentioned earlier as beta isomorphous elements. In combination with aluminum, they should produce alloy types similar to the Ti-Al-V and Ti-Al-Mo systems. However, they are less effective hardeners of beta than molybdenum, and it is not certain that, when alloyed with aluminum, they could produce properties similar to those of Ti-7 Al-3 Mo. Tantalum and columbium do raise the oxidation resistance of titanium, and it seems reasonable to believe that one might combine the greater strengthening capacity of molybdenum with the oxidation resistant characteristics of tantalum or columbium. This is a

*See "Enhanced Properties in 17-7 Stainless" (with data sheets) by M. W. Marshall, D. C. Perry and N. R. Harpster, *Metal Progress*, July 1956.

†According to data from Armour Research Foundation Progress Report No. 3 to Wright Field on Contract AF 33(616)-2853.

possible direction for further modification of the Ti-7 Al-3 Mo alloy.

In summary, it appears that Ti-Al-Mo alloys can produce a combination of properties which are better for elevated-temperature applications than the Ti-6 Al-4 V alloy, which is currently the most widely used titanium alloy. The specific alloy containing 7% Al and 3% Mo appears quite promising. It is clear that much work remains to elucidate the variables which control properties as well as reveal the mechanism by which they act. Some of this will have to await clarification of the Ti-Al phase diagram now being investigated, and the composition may be modified in accordance with information gained from studies of alpha-plus-compound and other alloys.

Hardenability

In steel terminology, hardenability is the term which refers to the depth of hardening after a standard quench. Roughly speaking, the greater the amount of martensite, rather than pearlite, formed during the quench the greater the hardenability.

In titanium, hardening or strengthening is produced when the beta phase, retained at room temperature by water quenching, is aged in the temperature range of 800 to 1100° F. Thus, to determine the "hardenability" of a titanium alloy, the Jominy end-quenched specimen must be aged; the greater the depth of hardening *after aging* the greater would be the hardenability.

Since it is the decomposition of beta which hardens (strengthens) the alloy, one might say that the greater the amount of beta which is retained the greater is the hardenability. In this sense, "hardenability" is somewhat of a misnomer, because retained beta is soft.

If there is insufficient alloying element to retain beta completely, hardening can take place during quenching by the formation of an unstable transition phase, known as omega*. If a series of alloys is quenched from the all-beta state, a hardness curve, as shown schematically in Fig. 4, would be obtained.

L. D. Jaffee, in an article entitled "Hardenability of Titanium Alloys Calculated From Composition" in *Journal of Metals*, 1955, p. 1245, has pointed out that Mo, Fe and Cr are the most potent in lending hardenability to titanium alloys. An addition of 6% by weight of any of these three elements, for example, would have twice the hardenability of Mn, 10 to 20 times that of V and 20 times that of Al. The effect on hardenability of Mo, Fe, Cr and Mn is additive and also not linear, the effect for each per cent added being quite small at low percentages and much larger at higher additions. The result of this is that a 6% Fe alloy of titanium would have the same hardenability as a 4% Mo, 4% Fe alloy. For low-density alloys it would be desirable to use iron or chromium rather than molybdenum, but as was pointed out earlier, iron and chromium cannot be used singly or together because the beta constituent containing these elements in solution will change into a brittle structure of alpha plus compound.

Phase diagram studies, however, show that if twice or three times as much Mo or V is used as Fe or Cr, the brittle alpha-plus-compound microstructure will not form. Thus it would appear that the necessary amounts of iron or chromium together with molybdenum would provide no strength-weight benefits over straight molybdenum additions.

So far there has been little industrial use of the age hardening properties of beta titanium, but as the technology develops, large sections of titanium will probably be hardened in this way. Special alloys will have to be designed for such uses and molybdenum will play a large role.

Vanadium will be a competitor in circumstances where low density is important and section size is small, since 1% by weight of molybdenum increases the calculated density four times as much as 1% by weight of vanadium. Thus, if the size to be hardened is sufficiently small that the amount of vanadium required is less than four times the necessary molybdenum, a lighter part can be made of the Ti-V alloy.

Price would also have to be considered. If the cost of using three times as much vanadium were the same or less than for the necessary molybdenum, there would be a clear advantage for the vanadium alloy, other factors being equal. If the cost of the vanadium alloy were higher, but lower weight resulted in an over-all economy in the structure, the advantage would again be on the side of the alloy containing vanadium.

The current government-sponsored program to develop sheet alloys will attempt to use the age-hardening characteristics of beta. The hope is that a sheet can be produced which can be quenched and retain soft beta, whereupon the sheet can be formed and then aged. Molybdenum and vanadium are the two beta stabilizers being considered in the program. Advantages

*This omega-hardened beta is quite brittle. Only by aging for sufficient lengths of time can omega be converted to alpha. The fine alpha dispersion in beta formed in this way produces a strong, often highly ductile material.

can be pointed out for either, but there now are too many unknowns to predict which will be most suitable for sheet production.

The alloys being actively studied in this group are as follows:

15% V, 2.5% Al	Mallory-Sharon
6% Mo, 3% Al	Rem-Cru
3% Mo, 1% V, 4.5% Al	Titanium Metals Corp. of America
6% Al, 4% V	Mallory-Sharon and TMCA

Weldability

Alpha alloys are weldable. However, present commercial alpha-beta alloys are not weldable, because the beta phase decomposes and embrittles during cooling after welding, a matter which is accelerated by the oxygen and nitrogen absorbed during open-air welding. The conditions correspond roughly to condition A of Fig. 4; the alloy would have to be heat treated to restore ductility.

If, after welding, the alloy is soft, it must correspond to a position to the right of B in Fig. 4. This, of course, means that it is highly alloyed with beta stabilizer. Good weld ductility has been observed at Battelle Memorial Institute in alloys containing 15 to 30% Mo, 20 to 30% V, 13 to 15% Cr and combinations of iron with these three. It is also reported* that "two-pass arc welds in beta alloys are often brittle, even for alloys in which ductile single-pass welds can be made. Apparently the cooling cycles of the two-pass welds were not rapid enough to produce ductile welds, as the heat effect of the second pass caused embrittlement. The embrittlement in some of these welds was overcome by post-weld heat treatments."

These difficulties were probably most pronounced for compositions close to B of Fig. 4 and less frequently encountered to the right of B.

The retained beta alloys to the right of B would probably be more readily fabricated than alpha alloys of the same strength level; this is probably their greatest advantage. The all-beta alloys would probably be restricted to low-temperature applications; at elevated temperatures they would embrittle. Under these limitations one might use combinations of Fe, Cr and Mn, modified with Mo and V, particularly for sheet and small section sizes. If the alloy contains more than 12 to 15% of Fe, Cr or Mn without Mo or V, it will tend toward inherent brittleness; below this 12 to 15% range, the alloys would be brittle after welding. If density is not the overriding factor, high-molybdenum alloys would be attractive because they transform with extreme sluggishness.

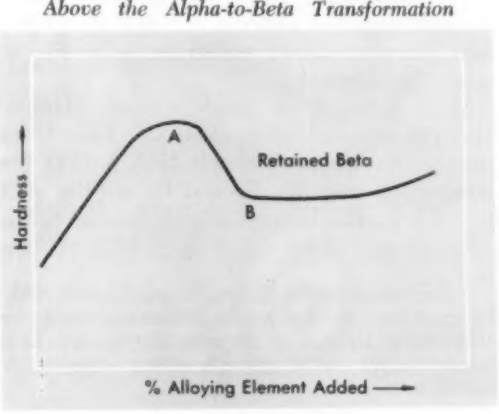
Influence of Molybdenum on Hydrogen Embrittlement

Hydrogen embrittles both unalloyed and alloyed titanium. In unalloyed titanium, this is revealed in the impact test, the absorbed energy decreasing with increasing hydrogen content. In alloyed titanium (specifically in alpha-beta alloys) hydrogen embrittlement is revealed by slow tensile tests or creep-rupture tests; with increasing hydrogen the reduction of area decreases, sometimes quite sharply.

The mechanism of hydrogen embrittlement of alpha-beta alloys is not understood.

A number of experiments have been tried to elucidate the influence of specific alloy additions, total alloy content, test temperature, strain rate and hydrogen content on hydrogen embrittlement. The results are summarized in Titanium Metallurgical Laboratory Report No. 27, wherein it is pointed out that all-beta alloys have a higher tolerance for hydrogen than alpha-beta alloys, and in the latter category the beta structure with molybdenum in solution maintains a considerably higher ductility than beta containing manganese. In alpha-beta alloys molybdenum also appears to promote greater tolerance for hydrogen than manganese. Similarly, a 5% Mo or 11% Mo alloy seems to have greater tolerance for hydrogen than the commercial alloy Ti-140 A (2% Fe, 2% Cr, 2% Mo). Aluminum additions appear to increase the tolerance for hydrogen;

Fig. 4 – Schematic Representation of Hardness Versus Alloy Content of Titanium After Quenching From a Temperature Above the Alpha-to-Beta Transformation



*"Welding of Titanium and Titanium Alloys", by G. E. Faulkner, W. J. Lewis, M. L. Kohn and P. J. Rieppel, Titanium Metallurgical Laboratory Report No. 31.

for example, a 6% Mn alloy is severely embrittled by about 270 ppm. of hydrogen, whereas a 4% Mn, 4% Al alloy is not embrittled until 1000 ppm. of hydrogen is introduced.

On this basis, titanium alloyed with 7% Al and 3% Mo might be expected to be quite favorable from the viewpoint of nonsusceptibility to hydrogen embrittlement.

Battelle Memorial Institute has also reported on the hydrogen "gettering" action of small amounts of beta stabilizer added to commercially pure titanium, as measured by changes in impact strength as hydrogen content increased. Of all the alloying elements added, 2% Mo proved best.

There are thus a number of indications that molybdenum is a highly desirable element in the sense that, when added to titanium, the metal more readily resists the embrittling effects of hydrogen.

Oxidation and Corrosion

A summary of the available information on the oxidation of titanium appears in Titanium Metallurgical Laboratory report No. 29. The mechanism of oxidation of unalloyed titanium appears to be quite complex. "Below 1100° F. a protective oxide film is formed and the oxidation rate decreases with time. In this range, the oxidation process is self-protecting and scale build-up is slow. Above 1100° F. protection must be provided by alloying, coating, or surface treating."

Investigation of several experimental alloys with binary to quaternary additions has shown that "those containing Al, Si, W, Cb and Mo, with or without Ta, appear to have scaling rates significantly lower than unalloyed titanium, while those with Cr, Fe, Mn and V scale at higher rates than the unalloyed metal". Although a number of the alloys reported on contained aluminum, they did not have better resistance to scaling than unalloyed titanium; this has been attributed to the adverse effects of the beta stabilizers in the commercial alloys.

The beneficial effects of the elements enumerated earlier generally occur at small total alloying – 5% or less. For example, 1% Mo alloy appears to have better oxidation resistance than a 4% Mo alloy. On the other hand, an alloy with 6% Al and 3% Mo has a lower scaling rate than a 3% Al, 1% Mo alloy and is more resistant to oxidation than the 6 Al-4 V alloy.

A number of the alloy combinations show better resistance to scaling than Type 302 stainless steel at 1600 and 1800° F. However, none of them would appear likely to have desirable mechanical properties. Of the beta stabilizers, molybdenum is the most potent strengthener of beta. Hence, it would be reasonable to believe that a useful alpha-beta alloy would contain molybdenum and one or more of the other alloying elements.

A Ti-Mo alloy containing 30 to 40% Mo has been patented by Rem-Cru Titanium, Inc. The patent claims that the 30% Mo alloy resists boiling 40% sulphuric acid and boiling 20% hydrochloric acid as well as platinum, tantalum or gold. Such a retained beta alloy is weldable and could be fabricated into sheet. These corrosion resistant characteristics would further add to the value of all-beta Mo-Ti alloys.

Book Review

NUCLEAR FUELS, edited by David H. Gurinsky and G. J. Dienes, D. Van Nostrand Co. Inc., Princeton, N.J. 364 p. $7.50

A Nice Reprint

*Reviewed by E. E. THUM**

WHATEVER ELSE may be said about the International Conference on the Peaceful Uses of Atomic Energy (to give the official title) held in Geneva in the summer of 1955, everyone will admit that the outpouring of some 1050 scientific and technical papers was unprecedented. The United Nations has published them in 16 volumes, containing close to four million words and uncounted tables, graphs and halftones, the set costing $130. If a fairly skilled and rapid reader would set himself to read these volumes, he would be busy for three months, working the standard 40-hr. week.

This estimate of wordage is enough to recommend the idea behind the present comparatively small volume. It is the first of a series of six

*Editor, *Metal Progress*

to be published under the editorship of James A. Beckerley, long director of classification for the U.S. Atomic Energy Commission. They are intended to cover the important aspects of reactors for research and for power, and the use of radiation in food production – thus limiting the field to a fraction of that explored at Geneva. This first volume contains sections on the production, alloying and fabrication of the metals uranium and thorium, on the effect of high-intensity radiation on fuel elements, moderators, fluids for heat transfer and on structural elements, and on the preparation and retreatment of fuel elements.

If one merely looks at the statistics he will discover that the subject matter of 26 Geneva papers containing about 110,000 words has been reproduced in one 330-p. book containing some 85,000 words. This is not much of a contraction. In fact when one compares this new book with the text of the original documents he finds that the editors have principally done a scissors and pastepot job.

This is really too bad, for Messrs. Gurinsky and Dienes, head of the metallurgy division and senior physicist of Brookhaven National Laboratory, surely have the information and the ability to present a critical digest of the subject matter, and to include much pertinent material (as they have in a few places) from the other open literature. One possible reason for the course which was taken is that each of the 26 Geneva authors presumably appraised the available literature he noted in lengthy bibliographies; another is that an original document would have taken a lot of time and labor; still another is that it might run into difficulties in declassification.

Nevertheless, such critical digesting is desperately needed – not only in the literature open to the public, but also in that large mass of documentation requiring an "L-clearance" for the reader. For example, the A.E.C.'s abstract journal in the first half of 1956 shows 393 public documents in metals, metallurgy, corrosion, ceramics and refractories. That is to say, Americans are producing documents on the constructional materials for reactors alone at a rate which equals the Geneva outpouring every 18 months. When the "gray area" open to L-cleared industry is included it would appear that we have a Geneva conference *every year* on materials of construction.

This stupendous mass of wordage must be systematically screened, appraised, critically digested if it is to be of much use to an insider and any use to an outsider. And who knows when an outsider may come up with an idea the insiders have overlooked?

Types of Furnace Atmospheres

*By CURTIS H. VAUGHAN**

The introductory paper at a joint session of Industrial Heating Equipment Assoc. and A.S.M. at the 1956 Metal Congress. Mr. Vaughan considers six basic sources for protective atmospheres, notes briefly their method of production, and variations in their constitution with variations in the operating equipment and the control settings. (J2k, B25; RM-g)

IN ANY ATTEMPT to consider broadly the topic of the selection and application of protective atmospheres, it is necessary to start by listing the principal atmospheres, their source, and the means of generation. Such a review should contain some of the basic principles involved in the selection of atmospheres for certain important industrial operations. A paper to follow next month on "Applications of Furnace Atmospheres", by Clarence E. Peck, will deal with specific applications, processes and products, and the *what* and *why* of these applications.

The various furnace atmospheres now used in the United States have been given individual names, most of which are trade names; some have come into rather general usage. In this consideration, however, I will use only the names which are descriptive of the actual atmosphere or means of generation.

Six Basic Atmospheres

In furnace work we are concerned primarily with six basic atmospheres. There are many variations of these six. Briefly, they are as follows:

First, and the one having by far the greatest general usage is exothermically produced combustion gas. Second, and also very widely used, is endothermically produced combustion gas. Third is nitrogen, which may be obtained from any one of three sources. Fourth is dissociated ammonia. Fifth is hydrogen. Sixth is an inert gas such as argon and helium.

These six basic furnace atmosphere gases and their variations include well over 99% of the atmospheres in industrial furnace applications in American industry. Actually they cover everything except a few quite special installations.

*Sales Manager, Electric Furnace Co., Salem, Ohio.

Exothermically Produced Combustion Gases

Exothermically produced combustion atmospheres are the product of the direct combustion of a fuel gas with air, the ratio of the two being accurately controlled to get any of several desired results. These ratios fall within two primary and two secondary control ratio areas in general usage. The chart shown in the data sheet, p. 96-B, shows the chemical analyses of these gases; the percent of perfect combustion is plotted horizontally while the amount of the various components is shown vertically. The first of the primary areas just mentioned is that having a gas-air ratio between 55 and 70% of perfect combustion; in the second the ratio falls between 90 and 98% of perfect combustion. The secondary ranges are those where the gas-air ratio falls between 70 and 90% of perfect combustion, and between 98 and 102%.

This exothermically produced gas is by far the most widely used in industry, and happens to be the first one developed. It needs only the simplest basic generating equipment, and it has the widest number and types of variations — all of which contribute to its extensive use. Another favorable factor is the fact that it serves fully, or with little compromise, the greatest number of applications.

The basic exothermic gas is generated in a unit which consists primarily of a refractory-lined gas-tight combustion chamber fitted with one or more standard burners to which a mixture of gas and air is delivered from ratio control and pumping equipment. This unit will also include a cooler through which the combustion products leave and in which a portion of the water of the reaction is removed. Figure 1 is a chart showing various adaptations of the equipment.

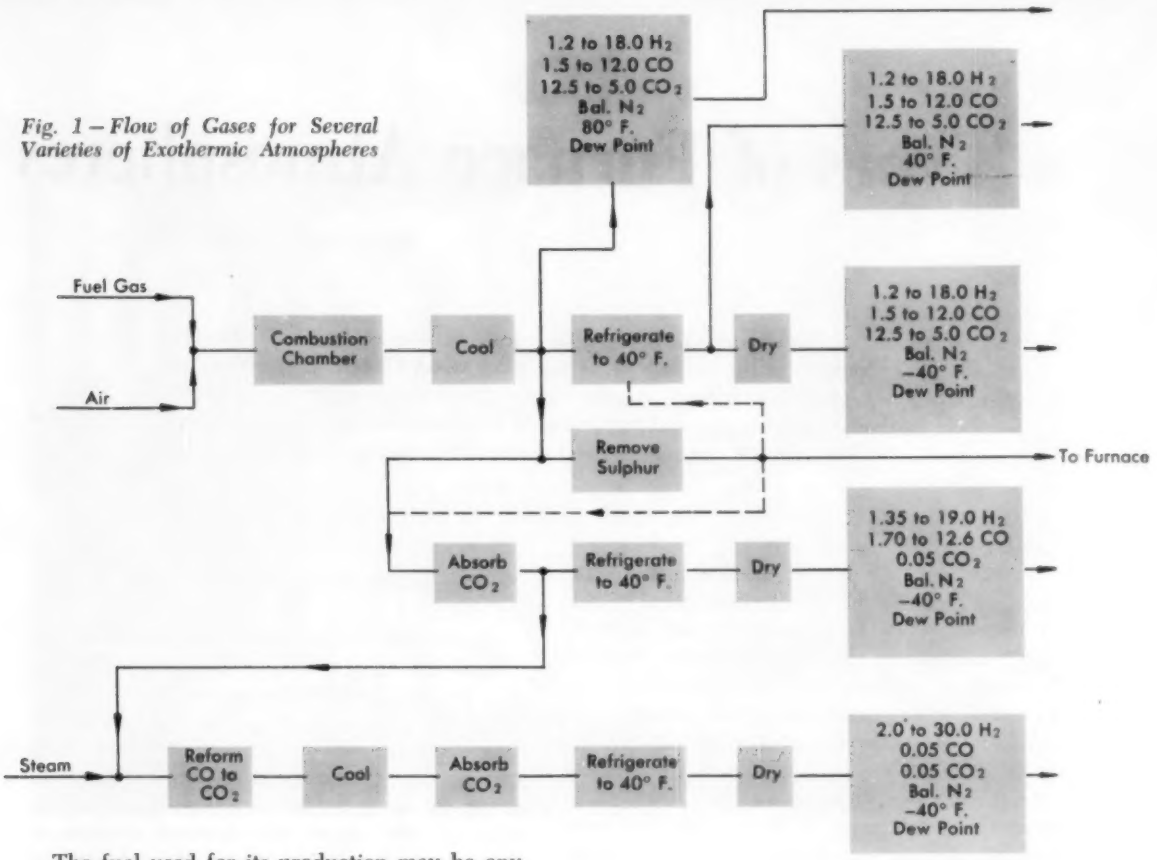


Fig. 1 – Flow of Gases for Several Varieties of Exothermic Atmospheres

The fuel used for its production may be any of the regular gaseous fuels, such as manufactured gas, natural gas, propane, butane, or mixed gases, or it may be a gasified oil or liquid kerosene. All of these are relatively cheap.

From this basic generator equipment, we get a gas that is a mixture of many elements and compounds, all of which are gaseous. Referring again to the data sheet we see that these are hydrogen, carbon monoxide, nitrogen, carbon dioxide, water vapor, sulphur dioxide, hydrogen sulphide, and minor amounts of others. The combustion reaction which produces this gas also produces heat in sufficient quantity to maintain a temperature in the reaction chamber from about 1600 up to 2600° F., which of course is sufficient to support the reaction.

The quantities of the various elements of the gas vary widely with the fuel-air ratio, as indicated in the chart (as does also the quantity of heat liberated). There is also some variation depending upon the fuel utilized.

In order to show the basis for a practical application of this exothermic gas atmosphere, it is necessary to consider its elements individually.

H_2 and CO – Both hydrogen and carbon monoxide are highly reducing and will range in quantity from 0% at 100% of perfect combustion up to approximately 18% hydrogen and 12% carbon monoxide at 55% of perfect combustion. In the heat treatment of most steel products, these two gases will prevent oxidation and the gas-air input to the generator will be dictated by the product and the heat treatment.

Nitrogen is, of course, almost completely inert and therefore is very desirable as a diluent. Since it comes from the combustion air, it helps to hold down the cost of the atmosphere. In most all considerations of exothermic gas, it is considered only as a desirable diluent.

CO_2 and H_2O – The carbon dioxide and water vapor are sometimes quite inoffensive in this furnace atmosphere, but they have some effects that are highly undesirable. Both are active decarburizing agents. Under some conditions they also oxidize the metal.

SO_2 and H_2S – In the general run of heat treatment of ferrous materials, small amounts of sulphur can be tolerated in the atmosphere, but if in large quantity SO_2 and H_2S may be very undesirable. The story is very different when the atmosphere is being used for copper or copper alloys. Here even traces of sulphur compounds, both inorganic and organic, are highly objectionable and they must be removed by suitable absorption towers.

Heat – While it might generally be desirable to retain as much of the heat in the atmosphere as possible, it is usually necessary to cool the gas both for removing water vapor and to reduce troubles in valves and other pipeline accessories.

In the copper and brass industries a very large part of the exothermic gas is generated directly *in the furnace* by regulating the furnace burners themselves, thus utilizing the heat from the atmosphere reaction to heat the furnace and the work – or, conversely, utilizing the heating gases to produce the protective atmosphere.

Variations in Basic Gas – The principal changes that can be made to the basic gas fall in three groups as shown on the diagram in Fig. 1. The first is the removal of water vapor. The second is the removal of sulphur compounds. The third is the removal of carbon dioxide.

Water vapor is removed first by refrigeration to take the dew point down to 40° F., and then by absorbing most of the remaining H_2O in a dryer unit usually employing activated alumina as the absorbent.

The inorganic suphur compounds may be removed in a stripping tower utilizing a solution of one of the amines as the absorbent. A much cheaper expedient, extensively used, is a combination wherein the sulpur dioxide is removed by water and neutralized by calcium carbonate, and the hydrogen sulphide is removed by passing through iron oxide chips to form solid iron sulphate and minor amounts of hydrogen gas.

The organic sulpur compounds generally are not of much consequence. In gases containing much of them the combustion should be carried out at 95 to 98% of completion, whereupon substantially all of the organic sulphurs are transformed to inorganic sulphur compounds and are removed as stated before.

Carbon dioxide may also be removed by stripping with one of the amine solutions or with a caustic solution.

The amine equipment for stripping sulphur or carbon dioxide consists primarily of a tower through which the atmosphere gas is passed in a manner to get good contact with the active chemical solution, and includes regenerating equipment for removing the carbon dioxide from the solution before recirculating.

Endothermically Produced Combustion Gas

Endothermic gas is the product of a reaction between air and a fuel gas carried out at high temperature. Here the ratio of gas to air is from 25 to 40% of perfect combustion. The excess of gas over air is actually so high as to require an external source of heat to support the reaction.

The major difference between the endothermic gas generator and the exothermic gas equipment is that the gaseous mixture is carried through the heating chamber in an externally heated retort. This requires additional combustion and temperature controls.

While the gas-air ratio on endothermic gas may vary between 25 and 40% of perfect combustion, the usual ratio is approximately 25%; the gas so produced contains less than 0.5% CO_2, slightly less than 20% CO, slightly less than 40% H_2, and the balance nitrogen. The dew point of this atmosphere will vary between zero and 30° F., depending upon many variations in the construction of the equipment. There also will be present a small amount of unconverted hydrocarbon, usually in the form of methane.

The designer and operator of the endothermic gas generator usually strive for the lowest possible content of CO_2 and H_2O, and at the same time maintain the lowest possible methane analysis. If it were possible and economically feasible, all three of these would be entirely eliminated, but this is not quite possible.

The chemical analysis of this gas will show the basis for its application and indicate what must be done to get additional usages. Reference is again directed to the diagram in the data sheet showing the approximate components, 38% H_2, 20% CO and 40% N_2 for a 25% combustion ratio.

CO_2 and H_2O – Both carbon dioxide and water vapor are decarburizing agents, but when held to a minimum this tendency is offset by other constituents in the gas and they do not present too serious an interference.

Methane – The unconverted hydrocarbons are very objectionable, but only due to their tendency to decompose and form sooty carbon which gives considerable trouble in pipe lines and in valves, and fouls up the catalyst.

Carbon monoxide, besides being a highly reducing agent, is also a source of carbon that will deposit on the steel in a heat treating furnace and carburize certain grades. It prevents decarburization of other grades of steel, and will reduce the rate of carbon loss at the surface of still higher carbon steels. The actual effects will depend greatly on the amounts of carbon dioxide and water vapor which are also present, on the temperature of the heating operation, and on the analysis of steel being treated.

Hydrogen is, of course, a strongly reducing agent and as such is desirable even though much

less hydrogen would usually be desirable from the standpoint of an explosion hazard.

Nitrogen is an inert element and very good to have in the atmosphere as a diluent.

The principal variations of endothermic gas come about by the addition of either a carburizing gas, a nitriding agent, or both. Thus, merely with ratio control equipment, we add percentages of methane (natural gas) or propane, and also can add desired quantities of ammonia gas through metering equipment.

Nitrogen, Ammonia, Hydrogen and Inert Gases

Nitrogen, when used by itself as a furnace atmosphere, is normally obtained from three sources – fuel gas burned with air, ammonia burned with air, and commercial tank gas.

To produce nitrogen from a fuel gas-air mixture, the equipment consists basically of an exothermic gas generator to which is added a CO_2 scrubber, a CO to CO_2 converter, a second CO_2 scrubber, and finally the drying equipment. A line diagram is shown at the bottom of Fig. 1. Such equipment becomes quite elaborate and complicated and includes many control devices, and its first cost is relatively high. However, it can produce nitrogen at the lowest cost.

The second source of nitrogen as a furnace atmosphere is from ammonia. We use either a nitrogen burner type of generator or a combination of an ammonia dissociator and an exothermic gas generator. In either event the fuel is liquid ammonia and the resultant is a gas which is substantially pure nitrogen containing a small amount of hydrogen – or, if desired, a controlled and larger amount of hydrogen. Water vapor is removed by condensation and absorption.

The third way to obtain nitrogen for furnace atmosphere is generally confined to small or intermittent usages, since the price of cylinder nitrogen is far too high.

The reason for using nitrogen as a protective atmosphere is that it is almost entirely inert to hot metal. It can contain small amounts of hydrogen to reduce light scale without having the problem of eliminating carbonaceous or sulphur compounds.

Dissociated ammonia is just exactly what the name says – the separation of ammonia (NH_3) into its two components (1 part N_2, 3 parts H_2).

Commercial dissociators consist primarily of a heated reaction retort containing a catalyst. Both retort and its heating chamber can take on various shapes; heating can be done in a variety of ways. Control equipment to maintain proper flows and proper temperature is required.

Dissociated ammonia is a relatively low-cost source of hydrogen gas having high purity and low dew point. Its nitrogen is not objectionable except in a few extreme instances where it may nitride the metal's surface. The great desirability of dissociated ammonia lies in the fact that it contains no carbon or oxygen compounds.

Hydrogen – Where the usages are small or the presence of nitrogen and other gases is undesirable, we are forced to use cylinder hydrogen for an atmosphere. Its cost is so great as to restrict it to small or infrequent operations, or to uses where no other gases can be tolerated.

Argon and Helium – In the past there has been little thought of utilizing these gases as furnace atmospheres. However, some recent developments, especially for highly reactive metals, have made their use desirable if not almost mandatory. They, of course, are absolutely inert elements. The difficulty is that they are sold only in cylinders and are quite expensive.

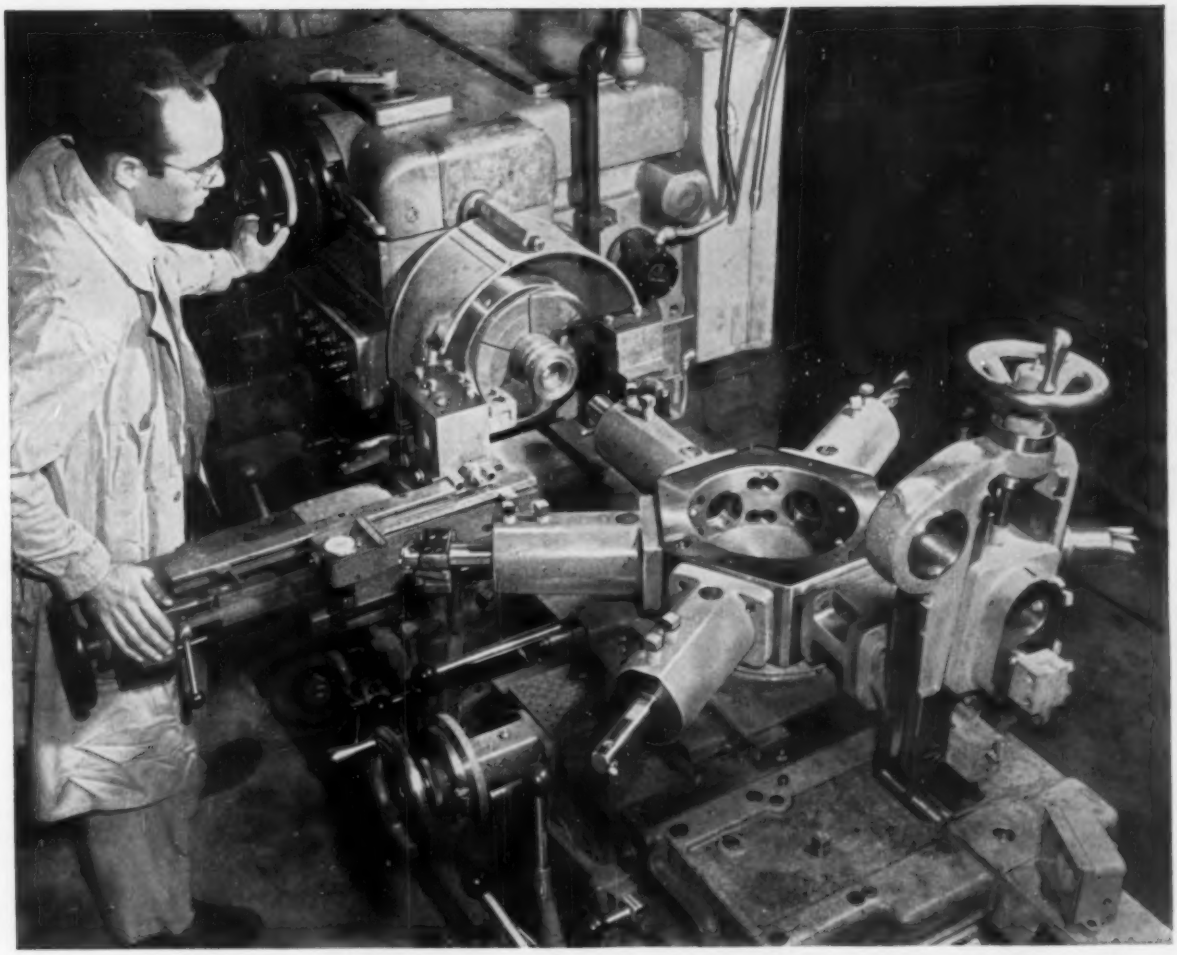
Conclusion

In the preceding sections we have attempted to outline the types of furnace atmosphere gases, the principal components of these gases, and the effect of the components. This outline forms the basis for the detailed discussion of atmosphere applications which will be covered in subsequent papers in this series presented by the Industrial Heating Equipment Assoc.

I have tried to show that the problem of furnace atmospheres has a great many approaches and a great many variations. These are so extensive that a thoroughly detailed study of the atmospheres and their applications is necessary to determine the proper usages. In addition, it has been pointed out that most of these atmosphere gases contain highly active portions of hydrogen and carbon monoxide, which, if permitted to mix with air and ignited, can be highly explosive. Carbon monoxide, furthermore, is lethal to humans; adequate care and ventilation are mandatory.

Thus, in addition to the study of the atmospheres themselves and the application of various heat treating processes, a complete understanding of the safety problems is necessary.

Another point which should definitely be made is that regardless of how properly the atmosphere is selected, how well designed the atmosphere generating equipment, and how carefully it is controlled, the atmosphere *within the actual furnace* is the one that affects the parts being heat treated. Thus, the design of the furnace must be just as carefully considered.



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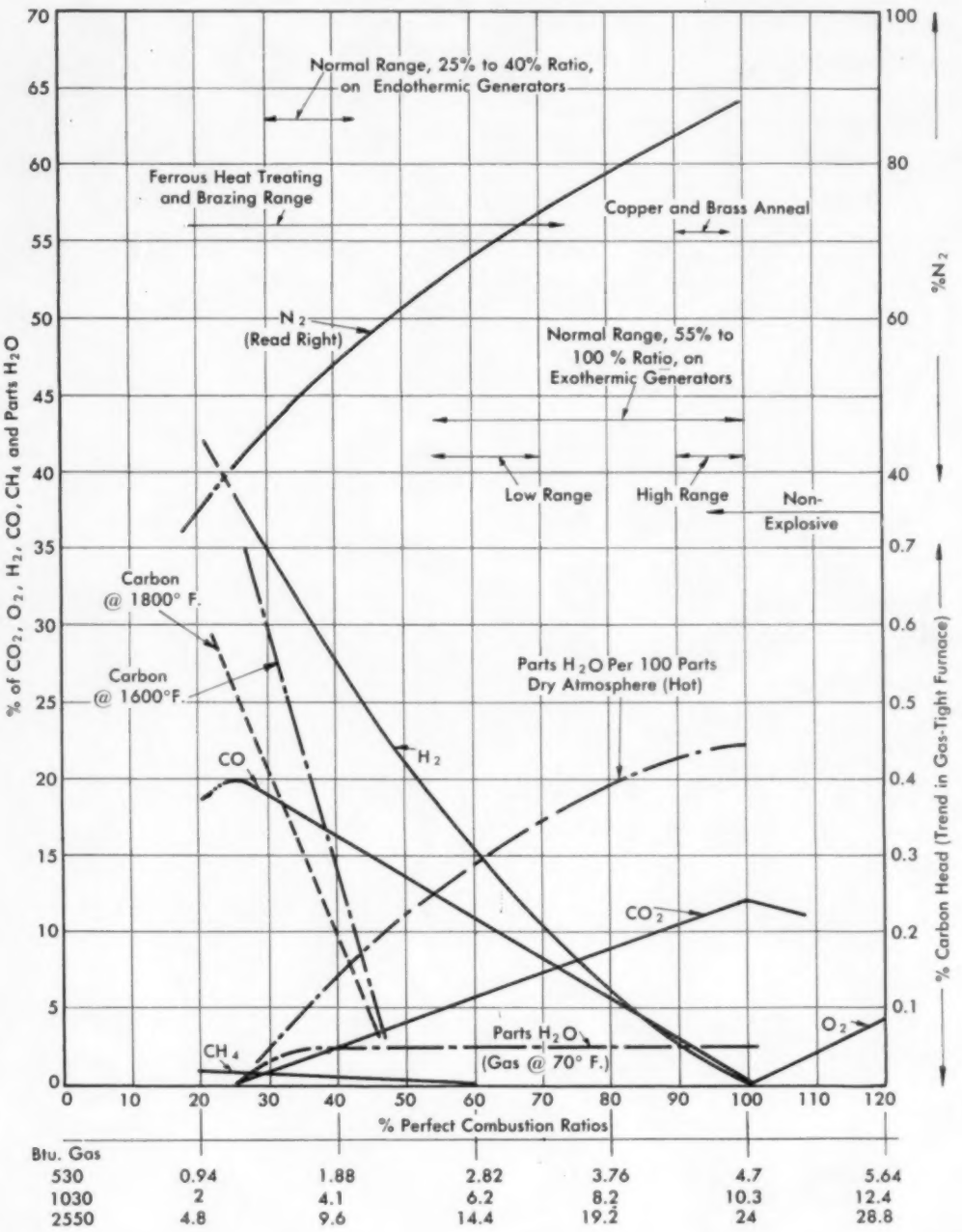
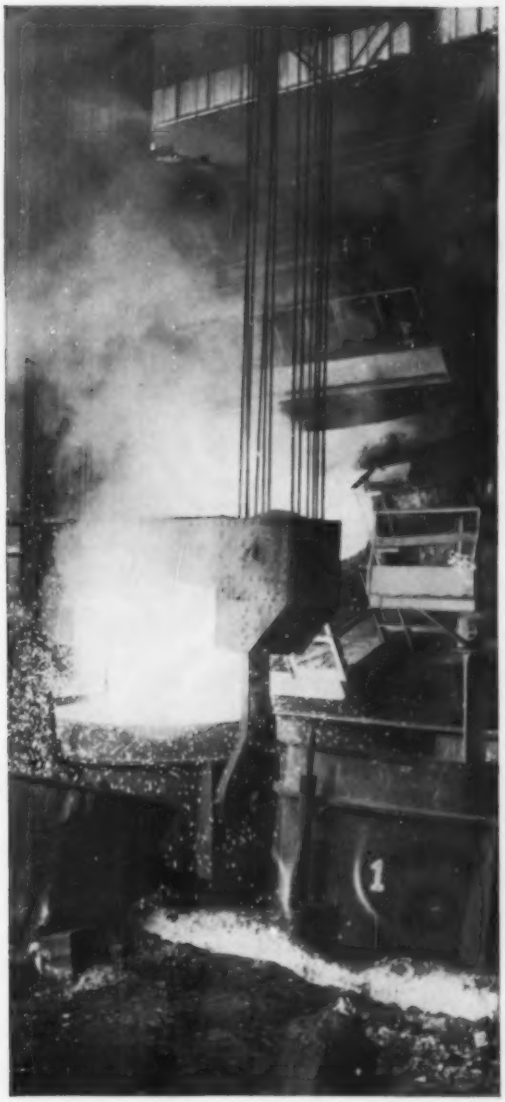
Furnace Atmospheres, Exothermic and Endothermic

By C. H. Vaughan


Normal Range, 25% to 40% Ratio, on Endothermic Generators
Ferrous Heat Treating and Brazing Range
Copper and Brass Anneal
N_2 (Read Right)
Normal Range, 55% to 100 % Ratio, on Exothermic Generators
Low Range
High Range
Non-Explosive
Carbon @ 1800° F.
Carbon @ 1600°F.
Parts H_2O Per 100 Parts Dry Atmosphere (Hot)
CO
H_2
CO_2
CH_4
Parts H_2O (Gas @ 70° F.)
O_2
% of CO_2, O_2, H_2, CO, CH_4 and Parts H_2O
%N_2
% Carbon Head (Trend in Gas-Tight Furnace)
% Perfect Combustion Ratios
Btu. Gas
530 0.94 1.88 2.82 3.76 4.7 5.64
1030 2 4.1 6.2 8.2 10.3 12.4
2550 4.8 9.6 14.4 19.2 24 28.8

While the chart presents average analyses of gas from many generators operating on natural gas, individual analyses may vary slightly with generator temperature, condition of catalyst, fuel gas analysis, air-fuel ratio, and whether city gas or propane is used for raw gas.

Carbon head determinations are obtained by running plain carbon steel specimens 2 × 2-in. size, cut from 0.001-in. strip of high and low carbon, through a gas-tight furnace. After exposure to gas atmosphere in furnace for at least 20 min. (or until equilibrium is reached) the specimens are analyzed for carbon. About eight specimens are required for one chemical analysis.



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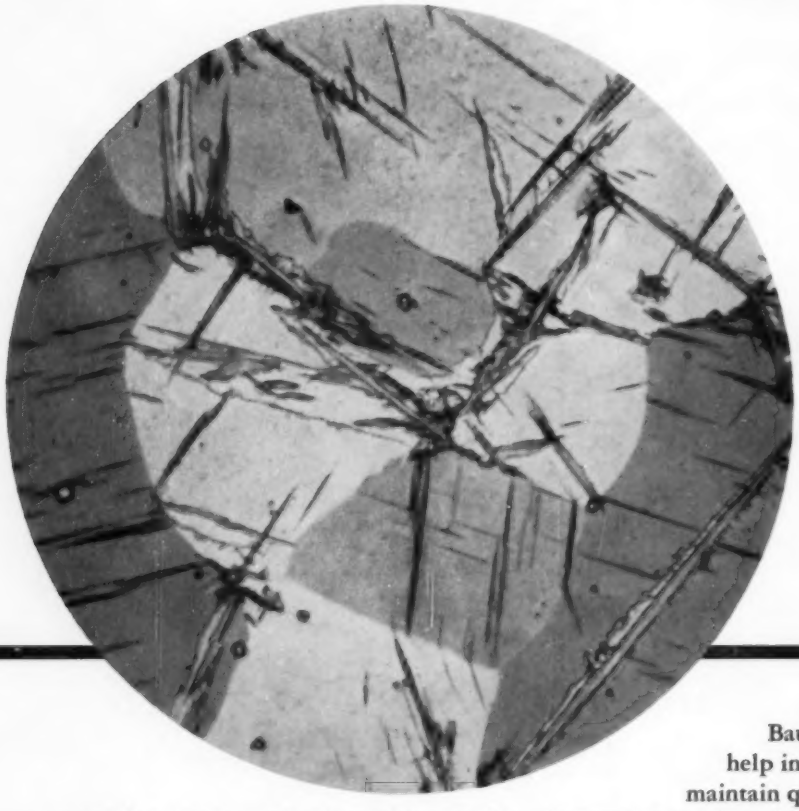

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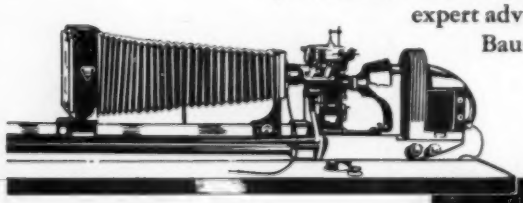

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Thorium's Role in Atomic Power

By JOHN P. HOWE*

This and the following two papers are from the conference on thorium held at the last ⚙ Metal Congress and Exposition with the help of the U.S. Atomic Energy Commission. The complete proceedings, containing 21 papers on various aspects of the metallurgy of thorium, are now being expanded to include information just made available by the new Declassification Guide, and will be published by ⚙ in book form in the summer of 1957. (T11, C6; Th, U)

ALL OF THE THORIUM which is accessible in the earth's crust will probably be mined and used up as one of our sources of energy in the next several hundred years. Its abundance is thought to be approximately three times that of uranium, but since it occurs in smaller concentrations, it may be that approximately equal quantities of the two elements will be available and together serve in one of our four major sources of energy – fossil fuels, nuclear fuels, radiation from the sun, and controlled thermonuclear reactions. Methods for utilization of the latter two sources of energy are not well enough known at present to play a definite role in our future planning. On the other hand, our plans for the next few decades *do* include nuclear fuels as a complement to our fossil fuels, especially in the regions where coal and oil are quite expensive or scarce. There seems to be no reason to think there will be a real competition between the various sources in the sense of one excluding the other.

Five major reactor projects which contemplate the use of thorium are now under way in the United States. Two of the reactors would use thorium or one of its alloys in metallic form. A third plans to use thorium as an intermetallic compound, while the fourth and fifth are being designed for thorium oxide in an aqueous slurry. The first three reactor concepts will provide the bulk of the material for this discussion of the role of thorium metal in the nuclear field. By summarizing the nuclear reactions involving thorium, the reactor types which utilize the material, the function of the thorium in these reactors, the manufacture and reprocessing of thorium-base reactor components, and some of the economic factors, the role of thorium in the nuclear field can be assessed.

*Chief of Research, Atomics International, Division of North American Aviation, Inc., Canoga Park, Calif.

Table I – Reactor Characteristics

	Solid Fuel		Fluid Fuel	
	CETR	SGR	HRT (HRE-2)	LMFR
Purpose	Power plant demonstration	Power plant	Test of a power breeder	Test of a power breeder
Fuel	U^{235} alloyed in Zr	U^{235} alloyed with Th at start, converting to U^{233}	UO_2SO_4 in D_2O	U dissolved in molten Bi
Moderator	H_2O at 1500 psi.	Graphite	D_2O	Graphite
Fertile material	Th metal, Zr clad	Th metal	ThO_2 slurry in D_2O	Th_3Bi_5 suspended in molten Bi
Heat exchange	Pressurized water to water and steam	Na to NaK to water and steam	Fuel solution to water-steam	Bi-U to NaK to water-steam
Thermal power	500,000 kw.	250,000 kw.	About 10,000 kw.	550,000 kw., full scale
Electrical power	130,000 + 89,000 kw. from superheat by oil; total 219,000 kw.	76,800 kw.	2,300 kw.	210,000 kw.
Breeding ratio	Greater than 0.8	0.8 without blanket; about 1.0 with optimum size and blanket	1.13	1.05
Status	Scheduled for construction; operation planned for 1960	Considered for second stage of sodium-graphite power reactors*	In construction; for test in 1956	Development stage of Brookhaven reactor experiment planned to be done by Babcock and Wilcox

*SRE (see line G, *Metal Progress* data sheet, September 1956; p. 96-B), a sodium reactor experiment, graphite moderator, using slightly enriched uranium, is nearly complete.

Nuclear Reactions – Since this article will be primarily for metallurgists, no effort will be made to discuss the physical principles involved. Those interested in the latter will do well to consult Paper No. 862 read at the Geneva Conference by A. M. Weinberg ("Survey of Fuel Cycles in Reactor Types"). Suffice it to say that natural thorium, which is almost 100% Th^{232}, will absorb thermal neutrons coming from the controlled fission of natural U^{235}. The Th^{232} thus becomes Th^{233} and this rather quickly transforms into U^{233}, which in turn is fissionable in much the same way as U^{235}. Thorium is known as a "fertile" material, and the atomic transformations leading to U^{233} as the "breeding cycle". If the efficiency of this breeding cycle is 1.0, a new atom of U^{233} will replace the atom of U^{235} which has just fissioned – you create exactly as much fuel as you consume!

For the next several years at least it will be necessary to use U^{235} as the fissionable material to initiate the thorium fuel cycle. As will be seen, some reactor types will always require a continuing supply of U^{235} and will be able to burn up only a portion of the thorium feed, using it primarily to sustain the reactivity of the reactor core in spite of burn-up of the U^{235}. Other reactor types may produce sufficient U^{235} so it will be the primary fissionable material.

In addition to natural U^{235} and artificial U^{233} (from thorium), there is a third fuel element Pu^{239} manufactured in the "piles" at Hanford and at Savannah River. The maximum possible breeding ratios for thermal neutrons originating from Pu^{239} is 1.03, whereas that for U^{233} is 1.25. Since these do not include some unavoidable losses in neutrons, the breeding cycle based on thorium stands the best chance of a breeding ratio greater than one – that is, for generating a somewhat larger amount of fissionable atoms than are consumed.

Reactor Types

Four reactor types, pertinent to this discussion, are as follows. The first two use solid fuel elements, the others use fluid fuel.

CETR – Consolidated Edison of New York; a pressurized water, thorium converter, power reactor.

SGR – Atomics International Division of North American Aviation, Inc.; a sodium-cooled graphite-moderated power reactor.

HRT (HRE-2) – Oak Ridge National Laboratory; an aqueous homogeneous power reactor.

LMFR – Brookhaven National Laboratory and Babcock and Wilcox Co.; a liquid-metal fueled reactor experiment.

These four are described, perhaps adequately for this discussion, in Table. The fluid fuel reactors have two regions of importance to this discussion: *(a)* the core, in which the fuel supplies fission heat and a source of neutrons; *(b)* a blanket, in which there is sufficent thorium to absorb nearly all the neutrons not needed for the chain reaction or lost to other materials. In their present form, the two solid fuel reactors have a core in which there is a mixture of the fuel material. In the CETR the fuel and fertile material are in separate plates but spaced very closely together. In the SGR, an intimate mixture of the two materials is used. While the relative advantages and disadvantages of the four types cannot be discussed at length here (and, in fact, will not be accurately known until the reactors have operated for some time), some chemical or metallurgical processes to be described are required to move the newly created fissionable material from the fertile elements to the region of the fuel elements (except in SGR whose fuel elements consist of a thorium-uranium alloy; presumably the only processing required would be the removal of fission products and reenrichment with fissionable material).

Table II – Comparison of Three Metallic Fueled Reactors

	CETR	SGR*	LMFR
Uranium required	275 kg.	360 kg.	175 kg.
Maximum metal temperature	345° C. (650° F.)	870° C. (1600° F.)	550° C. (1020° F.)
Steam temperature	290° C. (550° F.)	480° C. (900° F.)	480° C. (900° F.)
Efficiency	27%†	32%	38%
Th in reactor	9,700 kg.	8,100 kg.	21,000 kg.
Th consumption per yr.	125 kg.	72 to 90 kg.	180 kg.

*No blanket †Reactor only

Primarily because heavy water absorbs few neutrons and is an excellent moderator, HRE-2, the homogeneous reactor using thorium, has the best breeding gain, and approaches most nearly the ideal breeding ratio, 1.25. LMFR ranks next best within this group of four, and produces hotter steam. The two solid fuel reactors are a compromise in respect to the efficient utilization of thorium, but are worth exploiting because they have a number of advantages based on present-day technology. CETR, moderated with light water, perforce has a poor breeding ratio because neutrons are captured by hydrogen, but this disadvantage is offset to some extent by its low critical mass (and therefore low inventory) permitted by the excellent moderating properties of water.

Thus, each of the four reactor systems has its own advantages which must be tested by development, trial, and experience extending over many years.

Some data for the three reactors employing metallic thorium are given in Table II to show relative temperatures and the required amounts of thorium. Details concerning the thorium or its alloys as materials will now be given.

Thorium Metal in Specific Reactors

CETR – A schematic cross section of the fuel element planned for CETR is shown in Fig. 1. It will be seen that zircalloy-clad plates of U^{235} alloy (fuel) and thorium (fertile material) are separated by 0.10-in. channels for the coolant. The approximate changes in composition of the thorium plates during operation are shown in Fig. 2. The U-Zr alloy fuel element can be left in the reactor until at least 1% of all the atoms in the element have reacted, as which point approximately half of the U^{235} will have fissioned (and sufficient U^{233} formed in the thorium to equal slightly less than 1% of the thorium in the reactor). Fission products will be produced gradually at first, and subsequently at increasing rates so that nearly 0.5% of the atoms in the thorium will be fission product elements. A small amount of protactinium will be formed, but because of its decay to uranium, its concentration will be steady after a little over one month of operation. The properties of the thorium are not seriously affected by such changes in composition.

Sodium-Graphite Reactors – A perspective drawing of the Th-U alloy elements planned for the SGR reactor is shown in Fig. 3. Each cylindrical rod, about 10 ft. long, is an 0.455-in. round of Th-U alloy, clad in a 0.010-in. sheath of Type 304 stainless steel. The bond is a NaK alloy. Nineteen such rods are clustered as shown into a single group. Changes in the composition of this particular element with life in service are approximately as shown in Fig. 4. Although this represents more extensive alteration than Fig. 2 for CETR, this type of element may be expected to withstand such changes successfully.

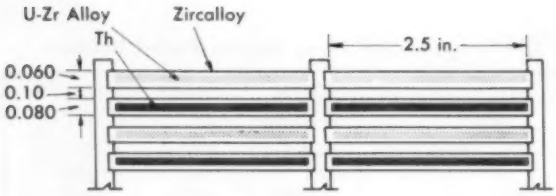


Fig. 1 – Cross Section of CETR Element, Alternating Fuel and Fertile Plates. Element is about 6 ft. long

Liquid-Metal Fueled Reactors – The essential metallurgical features of the thorium-containing bismuth slurry used in the LMFR have been described by R. T. Teitel, D. H. Gurinsky, and J. S. Bryner in an article entitled "Liquid Metal Fuels and Breeder Blankets" in *Nucleonics* for July 1954, p. 14.

Each particle of the thorium-bismuth intermetallic compound dispersed in the bismuth undergoes changes something like those described above. By processes of reforming the particles by dilution, heating and cooling, concentration, and continuous chemical processing of the slurry, the undesirable reaction products may be maintained at low concentrations in the particles and in the molten bismuth.

Properties of Thorium and Its Alloys

Uranium has but limited solid solubility in thorium – 2.8% at the eutectic temperature (1080° C. or 1975° F.) and decreasing to about 0.8% at 600° C. (1110° F.). It can be seen that the amounts of uranium which will be formed in the CETR will tend to form a second phase – although since the uranium atoms are created at random, and since their diffusion rate in thorium at the temperatures prevailing in this reactor will be low, a supersaturated solid solution may persist.

In the SGR, the initial Th-U Alloy will be two-phase, and the temperature of operation high enough so that the new uranium as it is formed will probably precipitate on particles already in existence. Evidence indicates that the uranium phase will probably be globular; although it is the poorly behaved alpha form of uranium, it will nevertheless be held in place by the thorium matrix.

It would seem that reasonable behavior of these fuel elements may be expected so long as the eutectic temperature (about 1080° C.) is not exceeded. At the higher burn-ups, a molten phase within the thorium might be expected to form and to promote the release of sufficient fission gases to cause swelling.

Preparation of Thorium for Reactors

The handling, melting and working of thorium bears some resemblance to similar processes for titanium and zirconium because of its chemical reactivity and melting point. Its ductility and strength are also not dissimilar to zirconium, although its mechanisms of deformation are quite different from the metals having hexagonal crystal symmetry.

The unit operations which are important in the preparation and handling of thorium for reactor components, subsequent to preparation of metal from the ore, are as follows:

Flat Plate Fertile Elements

1. Billet preparation, probably by arc melting.
2. Rolling of plate.

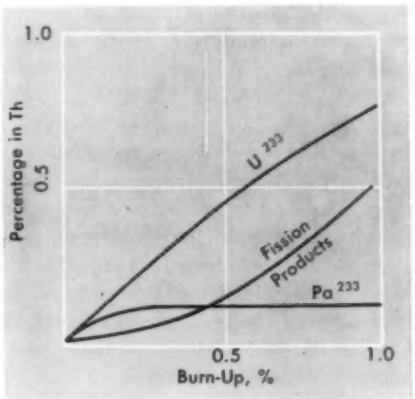


Fig. 2 – Increase in Amount of U^{233}, Pa^{233} and Fission Products in Thorium Plate of CETR With Amount of Burn-Up in Fuel Element. 1.0 atom percent of U-Zr alloy equals about half of the U^{235} contained

3. Roll cladding.
4. Inspection and quality control for dimensions, continuity of bond between basis material and cladding, and integrity of the cladding.
5. Assembly by brazing or welding.

SGR Fuel Clusters

1. Thorium-uranimum alloy billet preparation by induction melting.
2. Extrusion of bars.
3. Surface finish by swaging.
4. Machine cutting of slugs.
5. Cleaning.
6. Inspection and quality control of slugs to eliminate excessive voids and cracks which might

lead to nonuniform distortion of the slug.

7. Insertion in stainless steel tubes together with sodium-potassium alloy in the joints – all under inert atmosphere.
8. Welding the tube closures.
9. Inspection for bonding.
10. Assembly of the rods into bundles.

Preparation of Slurries

Thorium-bismuth slurries for LMFR may be prepared *(a)* by direct interaction between metallic thorium and bismuth, *(b)* by grinding thorium hydride, and *(c)* by direct reduction of a thorium compound in a bismuth melt (preferably by electrolysis). Massive thorium may be used by heating the two metals in contact at around 1200° C. (2200° F.). By using more finely divided material, such as chips, the reaction will proceed at about 500° C. (925° F.) and produce appropriately sized particles. A common way of comminuting the material is by starting with thorium hydride; after removing the hydrogen, and heating and evacuating, the finely divided material may be taken up in bismuth. Finally, the production of slurries by electroylsis is rather like the production of certain metal amalgams in which the molten alloy (bismuth) is a cathode in contact with the fused salt containing thorium.

Refining of Spent Elements

The thorium fuel plates used in the CETR will probably be processed by dissolving in nitric acid and putting the solutions through the "thorex" process, in which the fission products and protactinium are first extracted, then the thorium separated in a partition tower and concentrated; the U^{233} is stripped by ion exchange and the remainder sent to a solvent recovery system.

After isolation and preparation of pure thorium and uranium compounds, metal would be reduced and then refabricated into plates for the reactor. Uranium metal would be alloyed with zirconium for re-use.

Irradiation of these materials, unfortunately, causes enough radioactivity to require remote handling, which largely increases the cost of recovery and refabricating. This matter has not yet been thoroughly evaluated.

Similarly, if SGR elements containing thorium and U^{233} derived therefrom were to be used in the near future, chemical processing would be required. It is conceivable that this could be simpler than that outlined above since it would be necessary only to remove fission products and decontaminate. After reduction to metal,

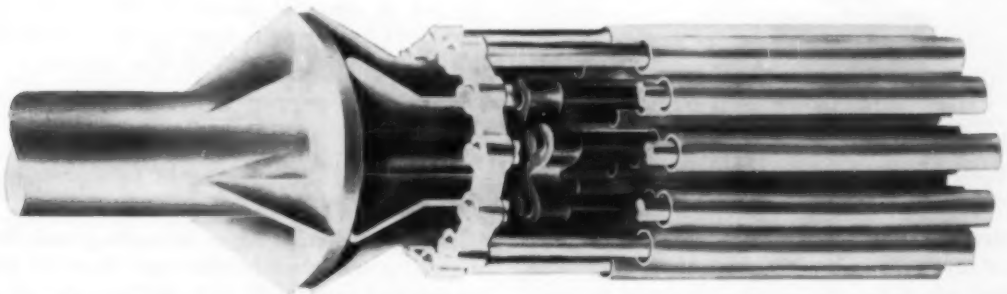
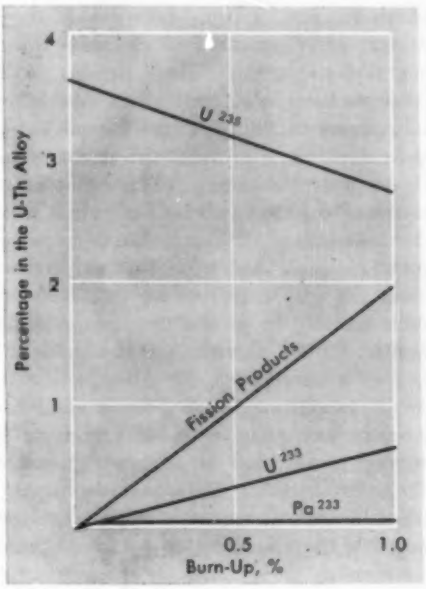


Fig. 3 – Perspective Drawing (Cut-Away) of Assembly of Fuel-Fertile Rods for SGR. Each long rod is a Th-U alloy, clad in Type 304 stainless steel

Fig. 4 – Increase in Fission Products, U^{233} and Pa^{233} in the SGR Element as the U^{235} Burns Up. When 1.0 atom percent of the fuel is burned up, 27% of the U^{235} has fissioned



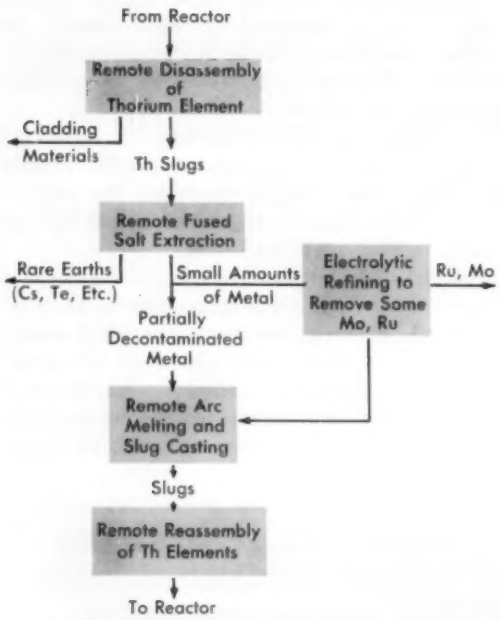


Fig. 5 – Flow Diagram of Laboratory Process for Processing of Thorium Elements in the Metallic State

adequate U^{235} would be added to bring the activity of the core to the proper operating value, after which the cylindrical slugs could be made by the processes mentioned above. The simplest possible procedures will be needed because of the induced radioactivity.

If the SGR can become a breeder, a blanket of thorium would be required around the core. Perhaps the reactor could be subdivided so the operator could remove fuel elements from the outer regions, remove their fission products, refabricate them into a unit which would then be placed closer to the center of the pile, step by step as the content of fissionable material builds up. At present it seems unlikely that practical schemes of this sort will be devised; it is much more likely that U^{233} will be removed from blanket elements and added to new core elements. Should the breeding gain of such a system actually be greater than unity (as it is estimated to be), thorium metal would be the only feed material.

Alternate methods have been studied in the laboratory for removing fission products from irradiated thorium while retaining the material in the metallic state. In this way we avoid the troubles of dilution, the use of organic extractants susceptible to decomposition by irradiation and the reduction of uranium compound. A conceivable but unproved flow sheet for such a process is indicated in Fig. 5. Fission products have been removed by the steps outlined sufficiently well to minimize the loss of neutrons by absorption in the remaining impurities. Levels of radioactivity, however, remain very high, being lowered by no more than a factor of 10 or 20. Since certain refractory metals less reactive than uranium are not removed in the indicated process –notably molybdenum and ruthenium–a small side stream is required to control their concentration to a few percent of the thorium, whereupon their presence does no harm to the metal itself, and the neutrons lost to them remain within tolerance so long as they amount to less than about 5%.

Costs of Fuel

Cost of electrical power in mils per kw-hr. produced by atomic reactors using the thorium fuel cycle have been estimated as follows:

Reactor	Cost
HRT (HRE-2)	1 to 2 mils
LMFR	About 0.22 for capital costs only
CETR	3.0 including oil for superheating
SGR	2 to 3

The predicted costs on an accounting basis for a given power plant involve many business decisions and agreements as to just how the plant will be operated and how materials will be exchanged between the operators and the Atomic Energy Commission. Therefore, many factors which determine the costs are not topics for a metallurgical discussion. However, the costs above have been estimated on an engineering basis and indicate the feasibility of the system. Furthermore, these estimates provide one of the reasons for proceeding with definite arrangements with the A.E.C.

The thorium cycle promises to be no costlier and possibly cheaper than the uranium cycle – a conclusion reached by an extensive study by K. L. Mattern ("A Study of Fuel Cycle Costs for SGR-Type Power Reactors", Document IDO-14363, Part II, April 1956, Technical Information Extension, Oak Ridge, Tenn.). Table III contains comparative figures from this study for the following processes: (*a*) extraction and direct refabrication and (*b*) pyrometallurgical or high-temperature processing and remote refabrication. These costs are not directly comparable with those given in the list immediately above because different sizes of solvent extraction plants are assumed. An interpretation of Mattern's studies indicates that inventory charges, together with

the chemical processing and re-enrichment, make up the largest portion of the cost of the fuel cycle. Thus, at the present time nuclear fuel is not cheap.

To lower costs, one objective would be to find a simple fuel recovery process which can be used at a specific power plant, and the estimated cost of processing the small quantities representing the throughput of a single 75,000 or 100,000-kw. plant indicate that it may be feasible to reach this objective.

It is true that the high-temperature processes considered in this study would be still cheaper when carried out on a large scale; nevertheless, the cost of shipping to a large central refinery might offset the savings. Pilot plant studies, just getting underway, will help to show whether such estimates can be realized.

have to await results from the sodium reactor experiment during 1957. One will probably not be built before the 1960's and, if built, will require at least 12 tons of thorium gross. The LMFR, which also should be coming along in the early 1960's, will require the reduction of 20 to 30 tons of metal.

In the years following the 1960's, the growth of the use of thorium will probably follow an exponential pattern, as do most growths, with a doubling time shorter than 10 years. If the predictions which have been made for utilizing atomic power are realized, and if the thorium cycles bear about half the burden of producing nuclear power, the total net investment of thorium in reactors may be 11,000 tons in 1975, with a replacement rate of 2 to 4 tons yer year. (This is based on an estimate that 10% of the power produced in the U.S. will be nuclear by 1975, principally in 100,000-kw. reactors, and equal amounts of thorium in process and in reactors.)

Table III – Relative Cost of Reprocessing as It Varies With Cycle Method and Size of Plant (Adapted From Mattern)

Item	Solvent Extraction and Direct Refabrication (Central Plant)		Metallic Refining and Remote Refabrication (at Power Plant)	
	Th-U Recycle	U Recycle, Pu Sale	Th-U Recycle	U Recycle, Pu Sale
Plant capacity, kg. per day	1000	1000	40	60
Ratio of inventory to re-enrichment and reprocessing charges	0.52	0.82	0.79	0.95
Ratio of fabrication to re-enrichment and reprocessing charges	0.045	0.19	0.12	0.49
Ratio of shipping to re-enrichment and reprocessing charges	0.066	0.20	0.0	0.0
Contribution of the above items to power costs; mils per kw-hr.*	3.13†	2.63†	2.21	2.18

*Estimates do not refer to an existing plant or to announced A.E.C. charges for processing.
†The burn-up for the two cycles is not the same.

The Role of Thorium

The element thorium may contribute an amount of energy in the long-range future greater than the expected total from our fossil fuel reserves. It is quite possible that a large amount of this thorium will be used in a fluid fuel reactor in which the optimum neutron economy breeding gain and hence optimum utilization of material may be obtained. In the nearer future, solid fuel reactors using thorium will make the largest use of metallic thorium. In particular, the CETR will require up to 15 tons of raw material, depending on the amount of processing scrap, to provide the 10 tons to be placed in the reactor. The net demand thereafter per year will be no more than approximately 100 kg. (220 lb.)!

The future of an SGR utilizing thorium will

If it proves to be impossible to achieve a breeding gain of unity or better in solid-fueled reactors, it is likely that they will pass out of the picture after the next 20 to 40 years, and the breeding cycles will take over. If the reactors fueled with liquid metal achieve a breeding ratio greater than unity, this design would probably become dominant since it produces power (heat transferring fluids) at temperatures comparable with good steam practice today.

Thus, thorium metal appears to have an important role in the nuclear power field, but the amounts used per year will not be large for some time to come.

Non-Nuclear Uses of Thorium

*By W. C. LILLIENDAHL**

Principal use of thorium metal in industry is very recent – for alloying with magnesium. Nearly all of the other uses are in the lighting and electronics industry, mostly as oxide. The oxide also has interesting possibilities as a refractory for very high temperature. (T1, W29, 17-7; RM-h, AD-n, Th)

THORIUM METAL and oxide are produced by highly specialized procedures. Their industrial applications are largely governed by their unique properties. For most uses no substitute exists. In many instances, competitive cost with other metals or oxides is not a factor, particularly where the demand is relatively low.

The potential use of thorium is very large (in comparison with present consumption) if one considers that when commercial nuclear power becomes a reality, a large stockpile of thorium as well as uranium will be required. (See the preceding article by John Howe.)

The major industrial application of thorium on a quantitative basis continues to be as oxide for making gas mantles, but the amount allocated for this purpose in the last few years has been decreasing while over-all uses in other fields show an increasing trend. The Bureau of Mines reports that in 1953 the thorium allocated for non-energy purposes was approximately 19,000 lb. of contained oxide, of which approximately 10,000 lb. was used for applications other than gas mantles. While the demand for thorium is increasing at a relatively slow rate, a notable exception is the allocation for magnesium-base alloys which is running into several thousand pounds per year.

The industrial applications of thorium are concerned with both the metal and oxide. The low tensile strength, elastic modulus and poor resistance to corrosion remove this metal from the list of structural engineering materials, but alloying and electronic uses are important.

Probably the best indication of the active interest in this metal and its oxide and other compounds is the recent bibliography by Helen Basil of Crane Co., which contains more than 800 references in the period 1951 to 1956.

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Alloying – The great increase in the last two or three years in the use of metallic thorium has resulted from the discovery that thorium is a desirable replacement for the rare earths (misch metal) in the magnesium-zinc-misch metal and the magnesium-zinc-zirconium-misch metal alloys described in Metals Handbook, 1954 Supplement, p. 75. The good creep resistance up to 500° F. of these older formulations is further improved until the thorium-containing alloys are serviceable up to 650° F. Large castings, such as compressor housings in jet engines, have been made. The alloys also are forgeable, and rolled sections and sheets are available for fabrication into complex structures where lightness, strength, and stability up to 650° F. are required.

Thorium metal is utilized as a deoxidant in such metals as molybdenum and its high alloys, and also in electronic tubes and lamps for controlling starting voltages and maintaining stability over their useful life.

Lamp Electrodes – The relatively low work function and high electron emissive properties of thorium are responsible for applications in several lamps of the gaseous discharge type, such as the high-pressure mercury arc, the "Sterilamp" and some low-pressure cold cathode lamps. A thorium electrode provides a low starting potential and sometimes a longer life than is obtained with the more conventional oxide coated Ba-Sr electrodes or thoriated tungsten electrodes. The metal is inserted in the form of wire into a tungsten helix as shown in Fig. 1. Sometimes thorium tabs are welded to the electrode – which may be nickel – or the metal may be sputtered onto the electrode.

The advantage of thorium is shown in the following figures, taken from a discussion of high-intensity mercury lamps by G. A. Freeman in *Electrical Engineering*, v. 59, 1940, p. 444.

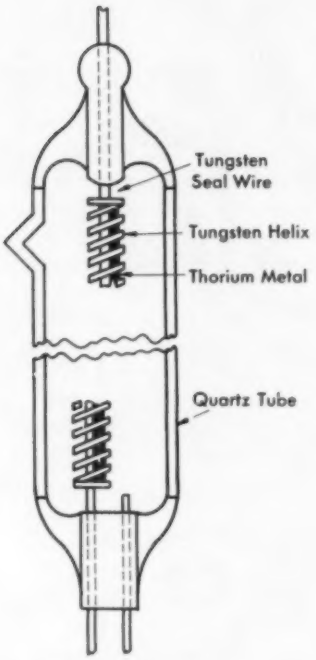


Fig. 1 – Sketch of High-Intensity Mercury Lamp, Using Thorium Metal Tab or Wire on the Electrodes

Operating Time	Lumens Output: Thorium Electrodes	Lumens Output: Oxide-Coated Electrodes
0 hr.	3610	3450
100	3260	3180
500	3090	2680
1000	3030	2320
2000	2620	1430

Welding – An expanding field for thorium metal and thorium oxide is in electrodes for inert-arc welding, where it provides an instant starting arc and improves the arc stability. Several compositions are employed but a relatively large amount of thoriated tungsten containing 1 to 2% ThO_2 is used. Patented compositions contain 100 parts tungsten and as much as 15 parts ThO_2 and 5 parts Ta_2O_5. Compositions of this nature are inherently brittle and must be produced by powder metallurgy.

Thorium has also been useful in the production of sound ductile joints in molybdenum. Tungsten arc welds of molybdenum sheet were improved with thorium metal additions. Welds made with 10% Th-Mo filler were ductile at room temperature.

An associated practice (although it relates to the oxide rather than the metal) is in the arc casting of metals. The current carrying capacity of an electrode depends upon the thermionic emission of the cathode and, to improve this, thorium oxide cores have been inserted into tubular tungsten electrodes. This lowers the work functions from 4.53 to 2.6 electron volts and lowers the temperature for a given current (or provides increased current at the same temperature). Arc stability is also improved.

Electronics – Thorium has been used in photoelectric cells for many years for the measurement of a wide band of the ultraviolet spectrum. The response of commercial tubes extends from 2000 to 3750 Angstrom units.

The "gettering" action of thorium has been discussed recently in several publications, but it seems doubtful that the unalloyed metal is superior to zirconium or titanium. However, if thorium is to be used for its emission properties, the basic gettering properties become important. Oxygen is irreversibly adsorbed. Nitrogen will be picked up but the nitride is unstable at relatively low temperatures in the presence of water vapor. At very low pressures, hydrogen is picked up by chemisorption. Its equilibrium conditions are such that thorium might be used in providing a constant low pressure of hydrogen as a so-called selective getter. Since the hydrogen pressure is an exponential function of the temperature, close temperature control must be maintained.

The above remarks apply to unalloyed metal. There appears to be some promise in the use of thorium alloys for gettering. For example, a Russian publication reports that the absorption of hydrogen in Ti-Th alloys exceeds that of zirconium. Getters composed of Al-Ce-Th alloys have been used and are said to pick up gases very efficiently at low temperatures.

Applications of Thorium Oxide

Many uses of thorium in metallurgy and ceramics basically depend upon the high melting point and stability of its oxide, coupled with a low dissociation pressure. For example, the melting point of thoria and competing oxides is:

Thorium oxide	3220 ± 16° C. (5830° F.)
Zirconium oxide	2710 ± 15° C. (4910° F.)
Beryllium oxide	2530° C. (4590° F.)
Lanthanum oxide	2210 ± 20° C. (4010° F.)
Aluminum oxide	2034 ± 16° C. (3700° F.)

The dissociation pressures of these oxides, as reported by Brace, are shown in Fig. 2.

These properties of thorium oxide are responsible for its importance in incandescent lights for controlling the grain size of the tungsten filaments. In pure tungsten the grain growth is rapid, forming large equi-axed grains subject to slip. The addition of 0.8 to 1.0% ThO_2 results in a small-grained stabilized structure, and filaments with improved hot vibrational strength.

The addition of 1.5% thorium oxide increases the temperature of perceptible grain growth in

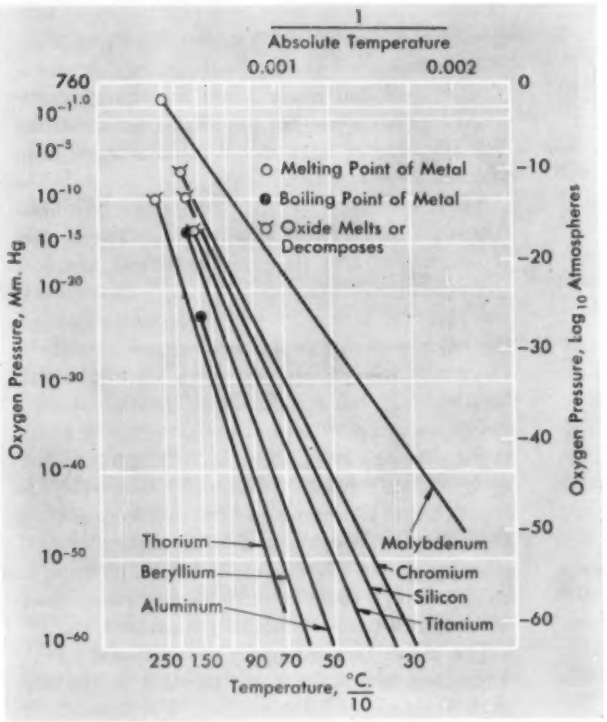
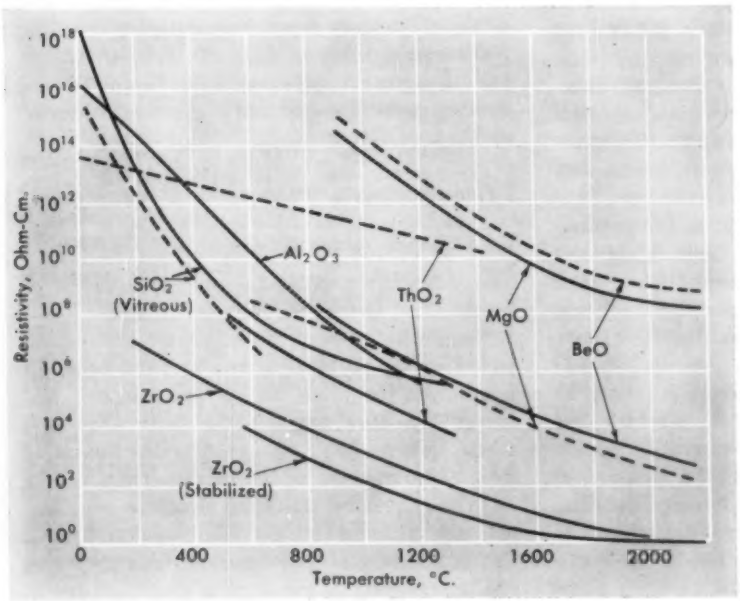


Fig. 2 – Dissociation Pressures of Metal Oxides at Various Temperatures. (*P. H. Brace*, Industrial and Engineering Chemistry, *Vol. 42, 1950, p. 227*)

Fig. 3 – Electrical Resistivity of Refractory Oxides. Wide variations are due to impurities. (From "High-Temperature Technology", by I. E. Campbell)



tungsten from 1200 to 2000° C. (2200 to 3600° F.). The increased hot vibrational strength probably results from increased grain-boundary strength.

In Electronics – These same systems are important in electronic tubes. In recent years several new combinations of thorium oxide and metal have been used as a primary source of emission. The oxide content is usually 1 to 2%, and their thermionic emission is treated in numerous publications. Notable new applications are those using thorium oxide and metals such as tungsten as a cathode emitter. Values of 14 to 15 amp. per sq.cm. at 1800° C. are reported as compared with 1 to 5 for thoriated tungsten operating at the same temperature. Mixtures of oxides with carbides or metal (cermets) have also been used; an unusually efficient cathode mixture has been reported by Bartol Research Foundation, composed of tungsten, tungsten carbide and 2% thorium oxide. The suggested reaction at the cathode is

$$2\,W_2C + ThO_2 \leftrightarrows 4\,W + Th + 2\,CO$$

and this appears to be possible thermodynamically.

In a study of the mechanism of electronic emission from thorium oxide cathodes M. Hoch and A. L. Johnson conclude that no reaction occurs between ThO_2 and W and that thorium is produced by the formation of ThO at 2125° C. (3850° F.) and the subsequent splitting of this compound into Th and ThO_2 at 1725° C. (3150° F.) or below, a hypothesis supported by X-ray diffraction analysis of the effused products. Progress is also being made in studying the possibility of electrolysis on emission. It would seem that this complex problem is approaching solution, which could improve the status of thorium in this field.

In other studies of emitters a number of investigators have examined the use of thorium coatings on molybdenum, complex oxide mixtures of ZrO_2 and ThO_2, and thorium boride. Thorium sulphides as thermionic emitters have also been investigated, as well as Mo-ThO_2 cermets as a source of electrons for magnetrons at frequencies of 20,000 megacycles. Any desired resistance in the latter may be obtained by varying the proportions of molybdenum and ThO_2.

Table I – Reaction of Metals with Oxides at 1800° C. (3275° F.) in an Inert Atmosphere

Oxides	Mo	Ni	Cb	Ti	Zr	Be	Si
Al_2O_3	A	A	A	B, C′	B, C′	B, D	B, D
BeO	A	A	B, C, D	B, C′	B	A, B	B, C
MgO	A	A	A, B	B, C′, D	C′	B, D	D
ThO_2	A	A	A, B, C	A, B	A, B	A, B	B, C
TiO_2	A	A	A, C	C′	C′	C′	C
ZrO_2	A	A	A, B	B, C′	A, B	A, B	D

A: No physical change at metal-ceramic interface.
B: Grain boundary penetration.
C: Corrosion of oxide.
C′: Considerable corrosion.
D: Formed new phase.

As a Refractory – Thorium oxide has been used to a limited extent for crucibles for melting several of the common and transition metals. With the exception of the nitrides of boron and magnesium, such operations under oxidizing conditions are limited to refractory oxides. Utility of oxide refractories depends upon the mutual solubility of oxide and metal, oxide stability, and metal-surface interactions which are difficult to predict. Consequently there is some doubt that thorium oxide, in spite of its high stability, is satisfactory for melting any of the oxygen-sensitive metals such as titanium, zirconium, or molybdenum. For example, Brace has melted titanium (in a vacuum) in thorium oxide crucibles and found the oxygen contamination greater than expected from the calculated oxygen dissociation pressures.

The thermal shock resistance of thorium oxide ceramics is relatively poor, and in many applications it must compete with aluminum oxide which can be used up to 1900° C. (3450° F.). The advantages of thorium oxide are shown at temperatures in excess of 2000° C., and beryllium oxide becomes competitive in this range. (Incidentally beryllium oxide is a satisfactory ceramic for casting thorium metal; wetting of the oxide is negligible and the solidified melt is easily removed by inverting the crucible.)

The most satisfactory oxides for melting such metals as Mo, Ni, Cb, Ti, Zr, Be, and Si have been determined by G. Economos and W. D. Kingery; their results, published in *Journal* of the American Ceramic Society for 1953, p. 403, are shown in Table I, which illustrates the general superiority of thorium oxide, but also the importance of proper selection to fit the actual requirements.

Crucibles of thorium sulphide may have an increasing number of applications, particularly where temperatures are not over 1800° C. (3275° F.). Thorium sulphide is reported to be superior to cerium sulphide at even higher temperatures and has been used for melting thorium. The monosulphide ThS is reported to have superior stability than Th_4S_7 and Th_2S_3; the latter dissociate above 1500° C. into ThS and S. Sometimes less metal adheres to the crucible with the higher sulphides.

As Resistors – The electrical properties of oxides in the group ThO_2, BeO, ZrO_2, Al_2O_3, and MgO are of interest as current carrying elements in high-temperature furnace design and insulation, particularly for temperatures above 1800° C., where a limiting factor for the refractories is often a high electrical conductivity. Oxides in the above group have negative temperature coefficients of resistivity which are influenced by purity (Fig. 3). (The two curves for ThO_2 are probably the result of different purity.) Thorium oxide appears to rate fairly well with the other oxides.

A good example of the use of thorium oxide as a semiconductor is shown in the resistance furnace described by R. F. Geller in Research Publication 1443 of the National Bureau of Standards (1941). The resistor itself is composed of 95% ThO_2 and 5% Y_2O_3 or La_2O_3. The contact blocks are 85% ZrO_2 and 15% Y_2O_3. Experience indicates that longer life at high temperatures is to be had from a resistor containing 85% ThO_2 and 15% CeO_2. One can expect an increasing use of this type of furnace for special high-temperature experimentation.

As far as the non-nuclear field is concerned, one might conclude from the above statements that the applications of thorium are now limited to a few major fields, with several other uses very much in the research or development status. It is reasonable to expect that an expansion in the nuclear field will result in lower cost and greater availability of this metal and its oxide, and this should stimulate the development of new and expanded industrial use.

A.E.C. Policy on Thorium

*By ALLAN M. LABOWITZ**

While much information concerning the properties of thorium is in the open literature, some important details on production and fabrication are still in the restricted area. The Atomic Energy Commission has, however, established a method for making restricted data available to individuals and organizations, known as the "Access Permit Program". Briefly, an individual (or an organization) having a potential use for restricted data in his business applies for an access permit, and if he meets the requirements (which are not unnecessarily restrictive), he is issued the permit and can then arrange for personnel clearances and facilities for storing classified documents while in his safekeeping.

Under his permit he may purchase any of a great number of reports of the Commission and its contractors dealing with the industrial application and utilization of atomic energy. He also may, under his permit, attend periodic information meetings and visit A.E.C. facilities. Virtually the entire work of the Commission in the fields of thorium metallurgy and the production of thorium metal is covered by reports available under the Access Permit Program. Many are "confidential"; others are "secret".

We have in preparation for publication about Jan. 1, 1957, a series of bibliographies – one for the unclassified reports, another for those which contain confidential restricted data and a third for those containing secret restricted data. The bibliography of unclassified A.E.C. reports will be available through the Office of Technical Services of the Department of Commerce. They are also available for inspection (as are all the unclassified reports) at any of the 50 depository libraries scattered throughout the United States. The bibliographies of the confidential and secret documents will be available to appropriately cleared holders of access permits.

These bibliographies and the reports which are abstracted in them, I am certain, will be helpful to anyone working in the field of thorium technology. Therefore, I wish to urge those who are interested in some phase of atomic energy and who do not already have an access permit, or whose organization does not have one, to apply to the U.S. Atomic Energy Commission, Division of Production, Washington, D.C. for such a permit. For those whose organization is or has been a contractor to the Commission, let me point out that this relationship does not provide the means for obtaining restricted data for use in the private ventures of the organization. The only means for so doing lies in the Access Permit Program.

Industrial Participation – The Commission has made it clear that it is anxious to develop commercial sources for the materials and services required by private industry in the field of nuclear energy. Until recently, the Commission has been the sole source for virtually all the unique materials and services required. We would like very much to see this situation change. This applies also to thorium.

At the present time, the demand for thorium metal by private industry for nuclear purposes is not great. Our estimate of the reasonably firm demand during the next several years by domestic and foreign users is in the order of ten tons of metal annually. We have nevertheless explicitly told all those who are interested in obtaining thorium to look first to the commercial market. We have told them that, before the Commission will undertake to supply any portion of their needs, they will be required to demonstrate that they have been unsuccessful in obtaining it from private industry.

In any event, the quantity of thorium which might be available to industry from the Commission is limited. Of course, progress cannot be impeded by the lack of thorium and the Atomic Energy Commission will therefore provide limited quantities, within its capability and in the absence of commercial thorium production. Such uses will undoubtedly be limited to research and development. Let me say that we will be disappointed if the lack of commercial production makes even this action necessary.

Some firms investigating the production of thorium have asked whether the Commission would buy metal from private producers. Our current needs for thorium in the Governmental programs are being met by our own facilities, and we do not anticipate such a need in the foreseeable future.

*Division of Production, U.S. Atomic Energy Commission, Washington.

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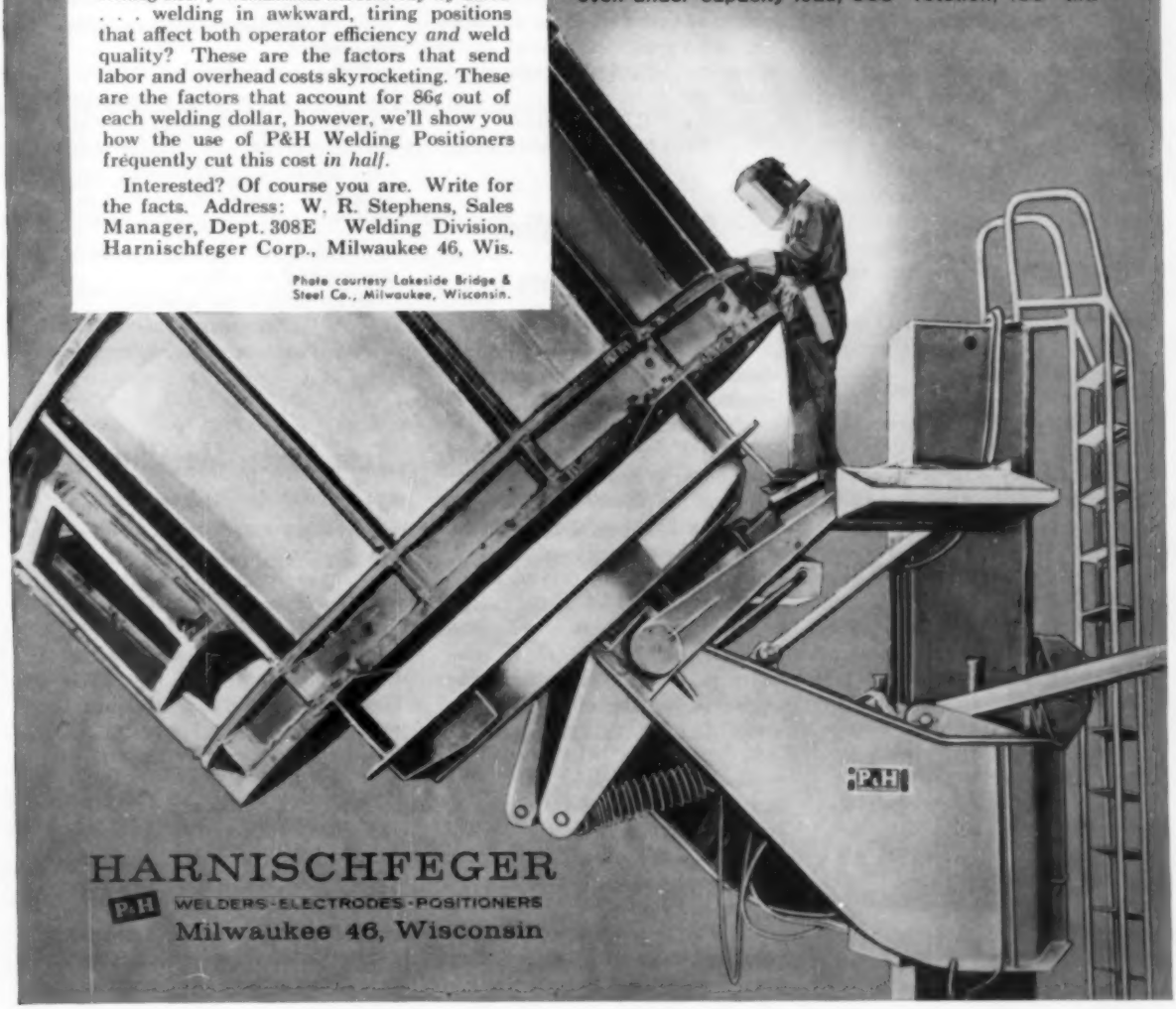

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Help in Choosing a Vocation

WINDSOR, ONTARIO

C. M. WHITE's article appearing in November *Metal Progress* entitled "Trained Manpower for a Technical Age" was read with interest. In that connection there is one idea that has been in my mind for some time concerning our high school pupils and the attempt by school boards to give the pupil some vocational guidance. My thought is that prominent industrialists could initiate concrete action in a specific approach to the proper people.

It seems to me that a great majority of our boys need much, much more than an hour or two a year from their schoolmasters to help them make a choice of a life work. At present the guidance councillor can do so little with the facilities and opportunities available to him.

What is needed, it seems to me, is a program by industry whereby high school pupils can get, during their first years, some practical, first hand, close contact and knowledge of what really goes on within a local industry. Perhaps an adaptation of the "cooperative" system of education which has had good success in some American engineering colleges could be devised, wherein the bright boy would spend a considerable amount of time with people who are making a livelihood in the work-a-day world. Definite curricular activities could be planned with days spent with an engineer, for example, where he can work with the people doing the job. A great many of the occupations could be open in this way for his inspection and participation to a certain degree.

All this would be with the intention of permitting the pupil to see just what a mechanical engineer (or any other professional person) has to do on his job. He would certainly be a better enlightened boy and better able to choose his life's work wisely.

A program like this would require the cooperation of a great many people of varied vocations and interests and a great deal of work setting it up, but I think the results would justify the trouble.

G. H. TALBOT
Ford Motor Co. of Canada

Alumni Doubling as Recruiters

CAMEBUSBURGH, U.S.A.

One consequence of the current shortage of young engineers is an enormous waste of faculty time by would-be employers.

Most of the visitors have legitimate business in our offices but they all seem to think that university professors have nothing to do but pass the day in pleasant conversation. The worst offenders are alumni who are coming back to the campus in increasing numbers as college recruiters. Since industry is using every possible device to hire more engineers, the alumni are doing the recruiting rather than men in personnel departments who may have graduated some place else. This lends a cozy atmosphere to the interviews and has been worth while.

Please don't misunderstand me. We are always happy to see old friends and alumni. All we object to is the way they fail to come to the point and waste our time in pleasant but inconsequential conversation. One of the jobs of any teacher is to assist in assessing and evaluating students for industrial placement. Hence, seeing and meeting these people is a legitimate and pleasant part of our teaching duties – but why, year after year, must we put up with the same old stories about the time the cow was locked in the girl's dorm, or old Professor Zilch had to compete with a hidden phonograph?

College professors have a job to do, just as people in industry. Queerly enough, the usual polite and circumspect devices used to terminate interviews fail totally when applied to these alumni visitors – probably because they are alumni and feel that they have privileges not enjoyed by others.

Help, help! Have a heart!

ZACHARIAH ZILCH
Professor of Metallurgy
Camebusburgh University

Tom Swift, Metallurgist

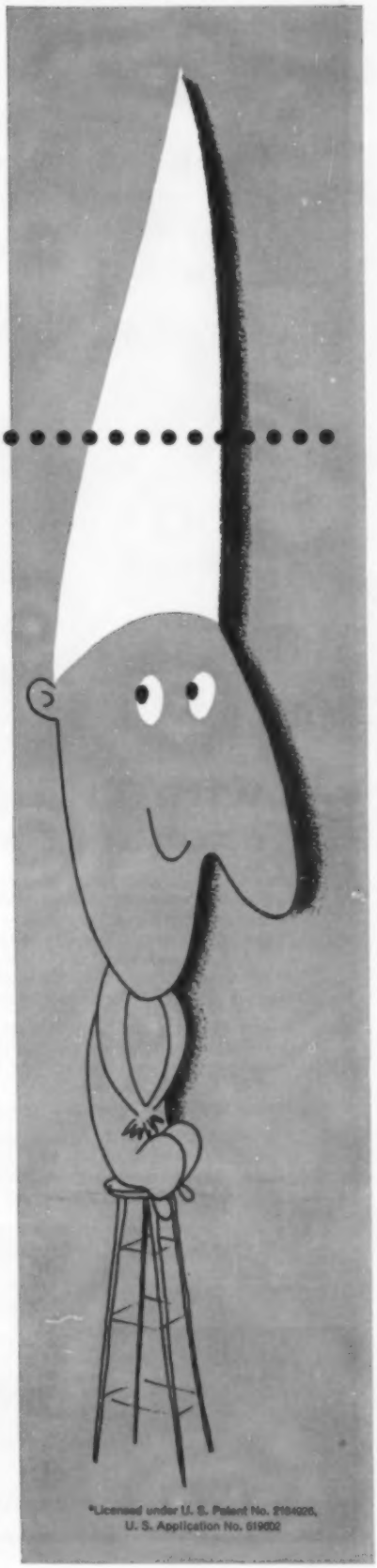
MADISON, WIS.

I venture a guess that many of the readers of *Metal Progress* who grew up in the period around World War I will fondly recall the prodigious feats of science, engineering, and adventure performed by the boyhood hero of those days, Tom Swift. The many Tom Swift books, written by Victor Appleton, will long be remembered by those of us who read them and eagerly looked forward to the next one.

As many are probably not aware, our boyhood hero has made his literary reappearance in the person of his son, Tom Swift, Jr. (written by Victor Appleton II, no less). Tom Jr. is carrying on in the true style of his father, albeit somewhat

It is obvious, of course, that we couldn't ask for, and get, $20 or $30 more per ton of shot and grit unless we could deliver substantial savings to the user every time! It is also obvious that we couldn't offer a guaranteed amount of savings (in writing) and in cash, starting with a premium price, unless we really had something! We have.

We weren't born yesterday!.....



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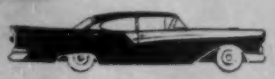
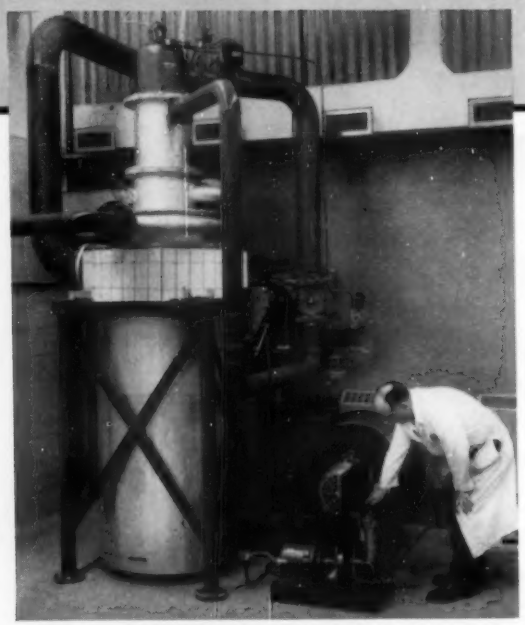


FORD

looks to the future . . .



with THERMAL heat exchange equipment

As part of its program of planning for the future, the Ford Motor Company maintains extensive research facilities. They recently expanded their scope of operations with the installation of a THERMAL Type DF heat exchanger for heating pressurized air. Ford has discovered, as have many of the nation's leading industrial firms, that these units are ideally suited to test facilities where sizeable variations in operating levels must be met quickly.

This Ford installation is typical of the expanding application of THERMAL heat exchangers to all phases of industry. Combining a maximum concentration of heat in a minimum amount of space, THERMAL units are supplied as complete package installations including all accessories and controls.

THERMAL heat exchangers are available in standard models with pressure ratings up to 300 psig., rated outlet temperature of 1200F and maximum heat transfer ratings from 250,000 to 8,000,000 BTU/hr. Higher output designs are also available.

For complete information write for Bulletin 105

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REPRESENTATIVES IN PRINCIPAL CITIES

Tom Swift . . .

streamlined, crew cutted, and with a generous dosage of modern electronics, atomics and scientific gobbledegook. There still remains the eternal struggle between good, clean, honest, fun-loving Tom, Jr., and the same sinister bad-guys.

However, Tom Jr. has discovered modern metallurgy in a big way, as witness the following passage taken from the book, "Tom Swift and His Flying Laboratory":

"But what about our trip to Verano?" Tom asked.

His father smiled. "I should be back here by the time you have installed new lifters in the *Sky Queen*. How about trying to invent a new heat resistant alloy?"

Tom spent the entire next day in the metallurgical lab, making various alloys of iron with titanium, tantalum, wolfram, and other metals of high heat resistance. These he carefully annealed and then etched in mineral acids to examine the crystal structure under a microscope. But when they were tested, none was an improvement over the material used in the original lifters.

Weary and discouraged, Tom tumbled into bed late that night. But with the morning sun came an idea which so excited the young inventer that he leaped out of bed with new enthusiasm . . .

Tom's long strides changed to an eager run as he neared the private entrance of Swift Enterprises. Few mechanics had arrived for work yet, but by the time Tom had calculated the last mathematical detail of the combination of metals, two engineers came into the metallurgical laboratory. Tom's formula excited them, and when the result proved to be a success a few hours later, they were elated. Tom named the new material "Mangalloy".

"That was a masterful idea, Tom," said Rick Bower, one of the engineers. "And it was so simple, too! Why didn't I think of it?"

Somehow, Tom Swift, Jr. seems to have lost some of the glamour of his famous father of 35 to 40 years ago!

DAVID J. MACK
Associate Professor
Metallurgical Engineering
University of Wisconsin

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Personal Mention

Carl F. Floe

CARL F. FLOE, professor of metallurgy and assistant provost at Massachusetts Institute of Technology, has been appointed assistant chancellor of the Institute. The office of the chancellor at M.I.T. administers the Institute's complete academic program and all academic officers are under its jurisdiction. Dr. Floe, who has had a good deal of experience in the academic and administrative affairs of the school, will represent the chancellor on all matters relating to research, and advise on matters relating to the professional schools and special projects such as new laboratories and other facilities. In addition, he will also carry administrative responsibility for M.I.T.'s summer session and for the library.

After graduation from Washington State College, Dr. Floe was an instructor in metallurgy until 1934 when he entered M.I.T. as a graduate student. Receiving his doctorate a year later, he returned to Washington State as an assistant professor. In 1936 he joined the faculty of Notre Dame University and three years later returned to M.I.T. as an assistant professor in the department of metallurgy. Here he rose to associate professor in 1942, executive officer of the department in 1943 and finally to full professor in 1950. He has held the position of assistant provost since 1952.

Chester B. Swander

CHESTER B. SWANDER, manager of the chemical and metallurgical department of Wagner Electric Corp., St. Louis, Mo., has retired after 40 years with the company.

A graduate of Purdue University, Mr. Swander was connected with Warner Gear, Muncie, Ind., Simonds Saw and Steel Co., Lockport, N. Y., and E. C. Atkins & Co., Indianapolis, Ind., before joining Wagner Electric in 1916. While with the Atkins organization, he worked with W. R. Chapin on heat treating experiments leading to the development of the S-curve.

He was first put in charge of heat treating high-explosive shells at Wagner; later he organized the chemical and metallurgical department for the company and helped develop it into one of the most important activities. Mr. Swander terms his work at Wagner as practical metallurgy, including writing material and processing specifications.

Mr. Swander joined the Steel Treating Research Society in Detroit long before its amalgamation with the American Steel Treaters Society to form the American Society for Metals in 1920. A charter member of the St. Louis Chapter, he served as secretary of the chapter for the first three years and later as chairman for two years. He is also a member of the American Society for Testing Materials.

Kenneth G. MacDonald has assumed new duties as product sales manager of furnaces and associated equipment in the industrial heating department, General Electric Co., Schenectady, N.Y. In this position, Mr. MacDonald will be responsible for sales of standard types of industrial heat treating furnaces manufactured by the department, as well as protective atmosphere equipment and furnace control. Mr. MacDonald held the position of product planning specialist in the department until his present appointment.

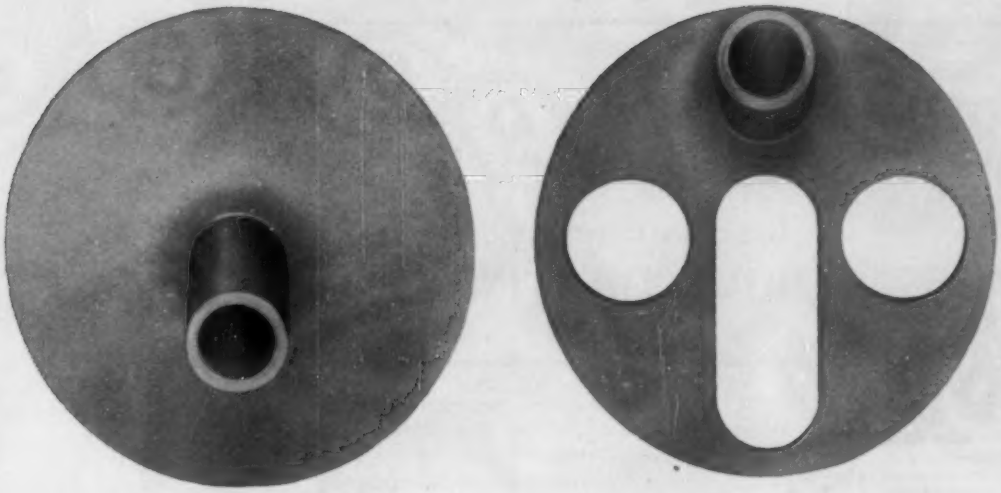
Harry L. Jenter, Cleveland district manager of operations for American Steel & Wire Div., U.S. Steel Corp., Cleveland, has been named vice-president, operations. Mr. Jenter succeeds **Van Leichliter** who was appointed president of the Wire Div. recently. Mr. Jenter joined the American Steel & Wire Div.'s Trenton Works in 1917, alternately working for the company and attending college. In 1928 he was transferred to the Cleveland Newburgh Wire Works as an assistant foreman, and later to the Cleveland Cuyahoga Works cold roll strip department. Rising rapidly in the company, Mr. Jenter was manager of operations for the Cleveland district until his present promotion.

E. R. McKinstry is now contact metallurgist at the Dayton, Ohio, plant of the Pittsburgh Steel Co. Mr. McKinstry was formerly with the company in Pittsburgh.

J. W. Spretnak has been promoted to professor, department of metallurgical engineering, at Ohio State University.

A. F. Sprankle, formerly connected with the steel and tube division, Timken Roller Bearing Co., Canton, Ohio, has been appointed assistant to the president and director of metallurgy of Northeastern Steel Corp., Bridgeport, Conn.

Stewart M. DePoy has taken a position as factory manager of the Lakeside Steel Improvement Co., Cleveland. Mr. DePoy was formerly a metallurgical engineering consultant in Akron, Ohio.



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in any shape or grade . . .

Can your product benefit from the important features shown in these Crucible Accumet® precision investment stainless castings? They are tube supports for jet aircraft engine assemblies, but the characteristics they illustrate are just as vital to thousands of other applications.

THIN WALLS — Accurately produced by the Accumet casting process, they are impossible to make in sand or shell mold castings — very difficult to forge.

BLIND HOLES — like this one, are impossible to forge, expensive to machine, and very difficult to sand cast . . . but they can be held to close tolerances by Accumet casting.

CORING — Deep or intricate cores — prohibitively costly to machine — can be economically produced by the Accumet process.

ODD SHAPED PARTS — difficult to chuck and machine, are economical when they're Accumet castings.

Next time your designs call for parts with intricate shapes . . . close tolerances . . . fine finish . . . high quality and uniformity, make them Crucible Accumet castings. They are available in any grade of steel or high alloy your product calls for. Let a Crucible engineer give you all the facts about how Accumet castings can save you time and money. *Crucible Steel Company of America, The Oliver Building, Mellon Square, Pittsburgh 22, Pa.*

Write for a **free** copy of the informative folder "Accumet Castings".

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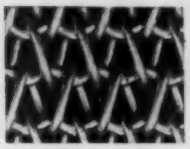
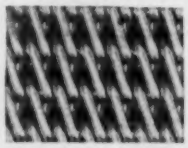
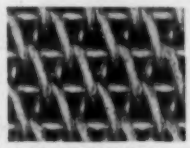
How to select WOVEN WIRE CONVEYOR BELTS for Continuous HEAT TREATING



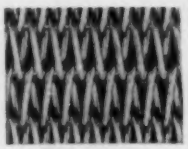
BALANCED—High tensile strength, low ultimate cost belting for operation up to 1300°F. Resists distortion. Designed for straight travel.



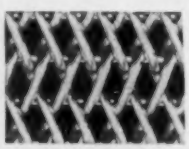
DUPLEX—Compact structure of great density provides high tensile strength, while close mesh provides smooth surface for carrying small parts.



ROD-REINFORCED—Highest tensile strength and low thermal capacity. Recommended for high temperature work, up to 2100°F. Undergoes minimum elongation and width contraction.



GRATEX—Close spirals retain the advantages of Balanced weave, while adding strength. For cold, medium and some high temperature applications.



DOUBLE BALANCED—A widely used weave combining open mesh of Balanced Weave with the strength of Gratex. For cold, medium and some high temperature applications.

As you know, woven wire conveyor belts are widely used for combining movement with processing in many continuous metalworking operations—brazing, annealing, sintering, quenching, tempering, washing, etc. Heat treaters, particularly, find that in all phases of their operations, belt-to-belt flow through processing eliminates manual handling, increases production efficiency and product uniformity.

However, there is no single type of belt construction suitable for all operations. Some must withstand the rigors of higher temperature service—up to 2100°F.; some require fine mesh for handling small parts; others must resist the corrosive attack of pickling processes and cooling operations. That's why Cambridge has nine basic weaves available in any metal or alloy. The five shown here are the most widely used in the metalworking industry.

There are several factors that generally influence selection of weave, mesh size and metal or alloy from which the belt will be woven. Among them are: size and shape of the parts to be handled, temperatures to which belt will be subjected, presence of wet or corrosive conditions. Even after these have been decided, overall belt construction must be designed to meet individual requirements—type of drive, selvage, support and special surface attachments must be selected.

You can see, then, that designing for continuous processing with woven wire conveyor belts is not a simple "nuts and bolts" job. Ramifications build up rapidly to demand the service of a specialist. That's why Cambridge maintains a staff of competent Field Engineers to help you select the Woven Wire Conveyor Belt to make your installation most efficient. You can rely on the experience of these engineers to specify just the right belt for you. In addition, they are thoroughly familiar with basic conveyor design. For the name of your nearest Cambridge Field Engineer, look under "Belting, Mechanical" in your classified telephone book. Or, write direct. Also ask for Special Report, "6 WAYS to Increase HEAT TREATING PRODUCTION", and 130-page Reference Manual of specifications and design information. THE CAMBRIDGE WIRE CLOTH CO., DEPARTMENT B, CAMBRIDGE 2, MD.

Personals . . .

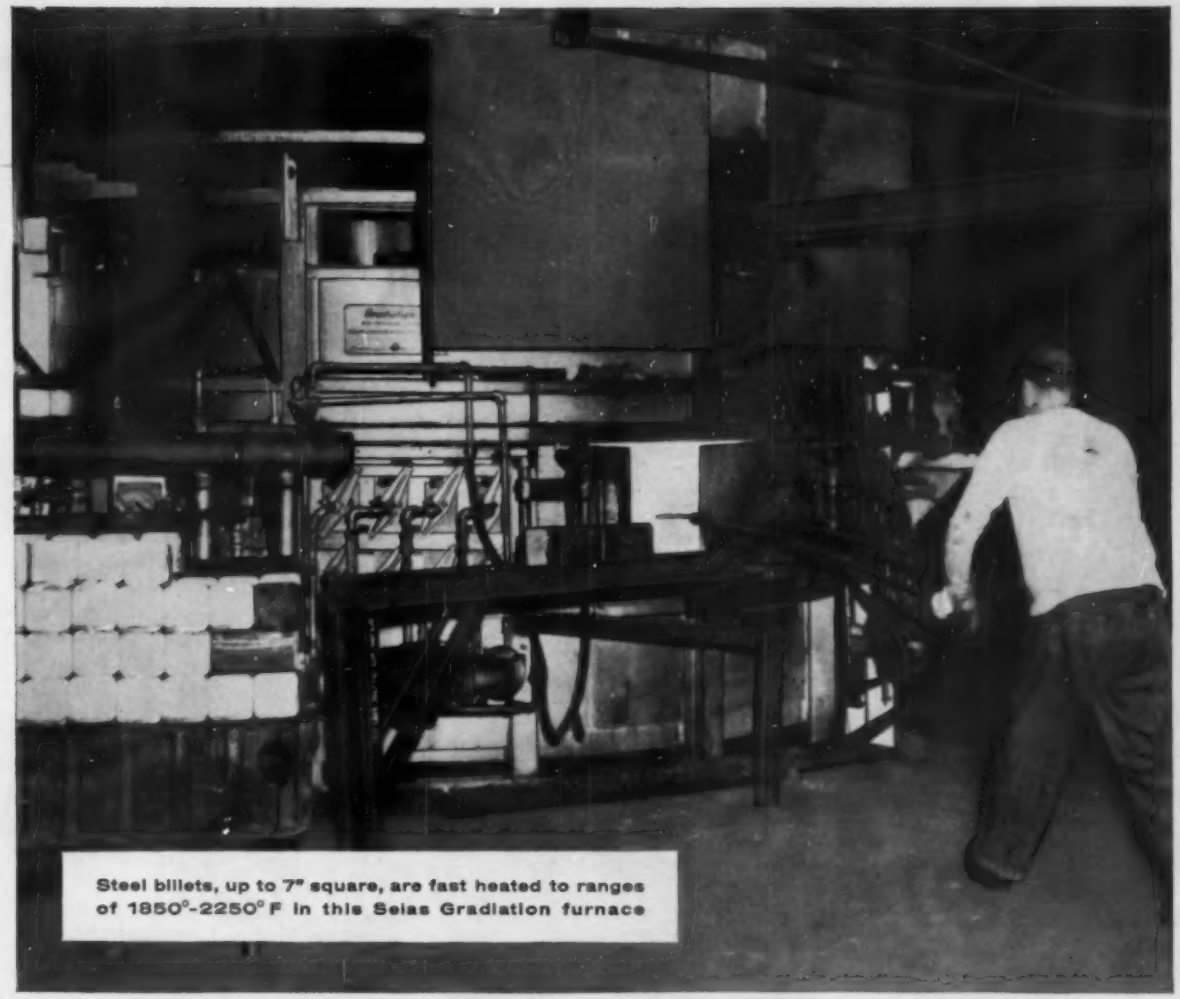
Leo J. Brancato has been appointed vice-president of the Heli-Coil Corp., Danbury, Conn. In addition to his vice-presidential duties, he will continue as head of the engineering department. Joining the company in 1952, Mr. Brancato rose to the position of chief engineer in charge of product development and research.

John E. Wilson has been promoted to the new post of general superintendent, manufacturing, for Marchant Calculators, Inc., Oakland, Calif., and will direct all of the company's manufacturing activities in both its Oakland plants. Mr. Wilson started with Marchant as an apprentice tool and diemaker, and last held the position of superintendent of the parts and production plant.

Charles E. Miller, recently appointed Houston, Tex., branch manager for the Carpenter Steel Co., Reading, Pa., is now in charge of the new mill-branch warehouse and office opened by Carpenter in Houston to meet the growing need for specialty steels in the Southwest. The new warehouse and office will provide sales and technical service to users in the Southwest, and takes the place of an office located in Houston for many years.

Herbert J. Arnold, until recently supervisor of stainless bar, wire and billet sales for the Crucible Steel Co. of America, Pittsburgh, has been named supervisor of stainless flat rolled product sales for the company. Since joining Crucible in 1945, Mr. Arnold has served in the capacity of general metallurgical sales engineer, general supervisor of the metallurgical department of the Sanderson-Halcomb Works, Syracuse, N. Y., and supervisor of stainless sales of Crucible's Cleveland branch.

Walter C. Chaffee has been named director of engineering for the Bennett Pump Div. of John Wood Co., New York. He will have his headquarters at the Bennett plant in Muskegon, Mich. Mr. Chaffee was manager of the engineering department at the Keller Tool Co., a division of Gardner Denver Co., Grand Haven, Mich., prior to his recent appointment.



Steel billets, up to 7" square, are fast heated to ranges of 1850°-2250° F in this Selas Gradiation furnace

FAST HEATING WITH *GAS*

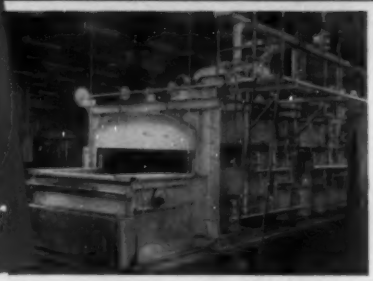
- improves forgeability
- reduces power requirements
- increases metal flow

A Gas-fired Gradiation® furnace designed and built by Selas Corporation for Lansdowne Steel and Iron Company, Morton, Pennsylvania heats billets to 1850°-2250° F at rates of 2 to 5 minutes per inch of thickness—thus virtually eliminating scale. Some fast heated billets are forged at temperatures 300° F below conventional methods.

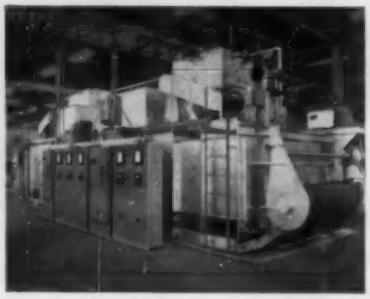
Improved forgeability, directly attributable to fast heating with Gas, reduces power requirements at the usual forging temperatures. Or, for given power applied, permits an increase in the amount of flow or deformation.

For information on how Gas equipment can help you in your production operations, call your Gas Company's industrial specialist. He'll be glad to discuss the economies and outstanding results you get with Gas and modern Gas equipment. *American Gas Association.*

4000 lbs. per hour



...in Automated Harden Quench and Draw



A large automotive plant required furnaces to heat treat 4,000 lbs. per hour of forgings or castings automatically. The equipment had to be durable to produce a constant uninterrupted flow of parts and also effect a substantial saving over previous methods.

Industrial's direct fired continuous belt type hardening furnace and famous "CIRC-AIR" draw are doing the job. Loading 35 lbs. per square foot of conveyor, hardening is at 1700 deg. F., quench in 1700 gallons of oil and temper at 1200 deg. F.

The rugged, dependable Industrial furnaces are completely automatic; produce 4,000 lbs. per hour every hour every day.

Besides saving man hours, there is a 20% fuel saving by use of the continuous belt conveyor operating wholly within the hardening furnace.

Industrial's "CIRC-AIR" draw furnace is the most efficient heating machine made for temperatures up to 1300 deg. F. High velocity fans force recirculated hot gases through the work with no temperature head. Thin and thick sections come to heat evenly; and the entire load is heated uniformly.

Send for "CIRC-AIR" Bulletin No. 13-A

CIRC-AIR

INDUSTRIAL
HEATING EQUIPMENT CO.

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PIONEERS AND STILL LEADERS IN RECIRCULATION

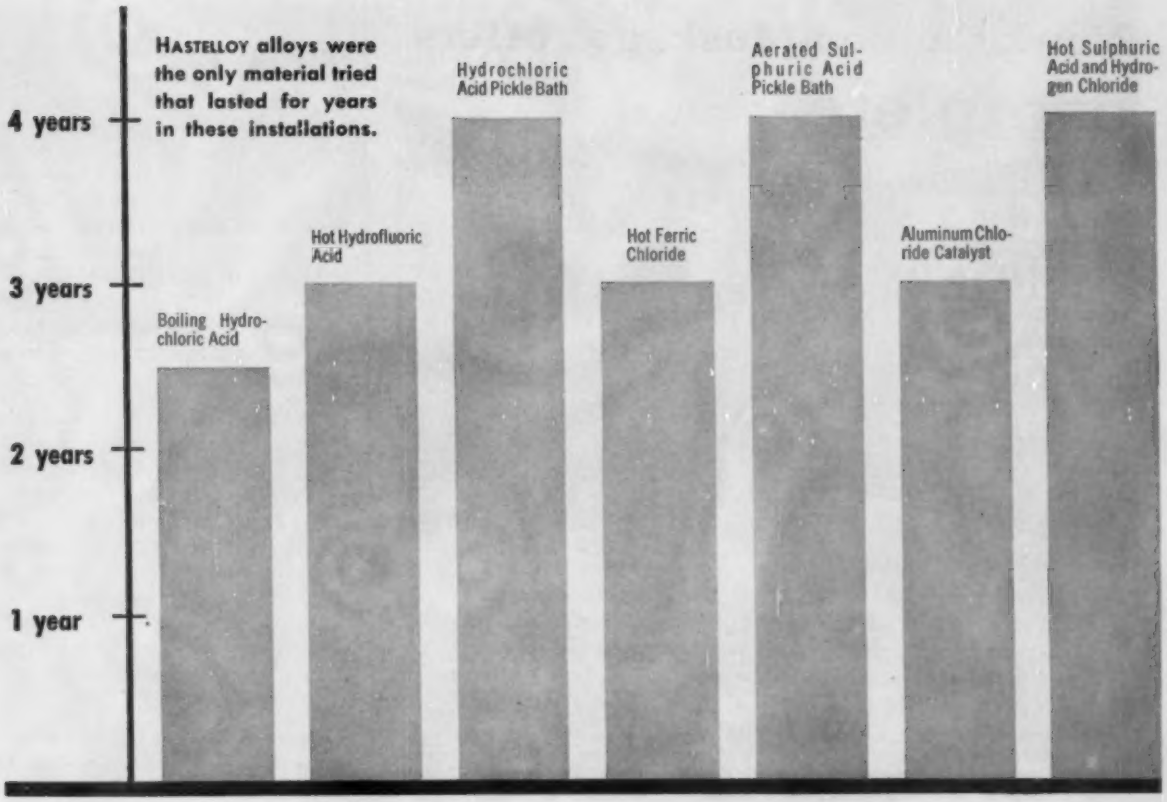
Personals . . .

Joseph P. Foley has been named by the Baldwin-Lima-Hamilton Corp. to handle sales of SR-4 strain gages, devices and systems as well as other electronic equipment produced by the company's Electronics and Instrumentation Div., Waltham, Mass. Mr. Foley, whose headquarters will be in Cleveland, will also continue to represent Baldwin-Lima-Hamilton in the Ohio area for testing machines.

Frederick E. Graves has been appointed to a new technical sales post as assistant to the vice-president in charge of engineering and research for Russell, Burdsall & Ward Bolt and Nut Co. Mr. Graves was formerly eastern sales engineer for the Lindberg Industrial Corp. He has also worked in engineering and research for Surface Combustion Corp., Battelle Memorial Institute and Youngstown Sheet and Tube Co.

A. E. Watts is now vice-president in charge of plant operations for Sun Tube Corp., of Canada, Ltd., a subsidiary of Sun Tube Corp. of Hillside and Washington, N.J. Mr. Watts joined Sun Tube of Canada when it was organized in 1946, and prior to that was plant superintendent for Modern Containers Ltd.

Several members were honored at the fourth annual meeting of the Investment Castings Institute in Detroit last fall. **Ted Operhall**, **Nicholas J. Grant**, **Roger Waindle** and **Richard A. Flinn** were presented awards for their outstanding contributions to the welfare and progress of the investment casting industry and the Institute. Mr. Operhall is president of the Misco Precision Castings Co., Whitehall, Mich., and a co-founder of the Institute. Dr. Grant, a professor at Massachusetts Institute of Technology, has served as the technical consultant for the Institute since its inception. Mr. Waindle, president of WaiMet Alloys Co., Detroit, was honored for his work in writing the metal specifications code of the Institute, and Dr. Flinn for his liason work between the Institute and the universities, which has resulted in the addition of special investment casting courses to the metallurgy curriculum of many universities and technical schools.


HASTELLOY alloys were the only material tried that lasted for years in these installations.
4 years
3 years
2 years
1 year
Boiling Hydrochloric Acid
Hot Hydrofluoric Acid
Hydrochloric Acid Pickle Bath
Hot Ferric Chloride
Aerated Sulphuric Acid Pickle Bath
Aluminum Chloride Catalyst
Hot Sulphuric Acid and Hydrogen Chloride

HASTELLOY Alloys *last for years under severe corrosive conditions*

These graphs were drawn from data on actual installations of HASTELLOY alloys in severe corrosive media. No other material tried lasted more than six months in most of these installations, some considerably less than this. HASTELLOY alloys lasted for years.

Use of HASTELLOY alloys saved time, money, and production time in all the installations. The graphs do not tell the entire story by any means. Some of the parts made of HASTELLOY alloys were still going strong when the data were obtained. In some, corrosion was complicated by abrasion, impact, and the presence of contaminants.

Samples for testing HASTELLOY alloys under actual operating conditions are available without obligation. Just let us know what corrosive conditions are involved. For a copy of a booklet describing HASTELLOY alloys, get in touch with the nearest Haynes Stellite Company Office.

HAYNES TRADE-MARK ALLOYS

HAYNES STELLITE COMPANY

A Division of Union Carbide and Carbon Corporation

UCC

General Offices and Works: Kokomo, Indiana

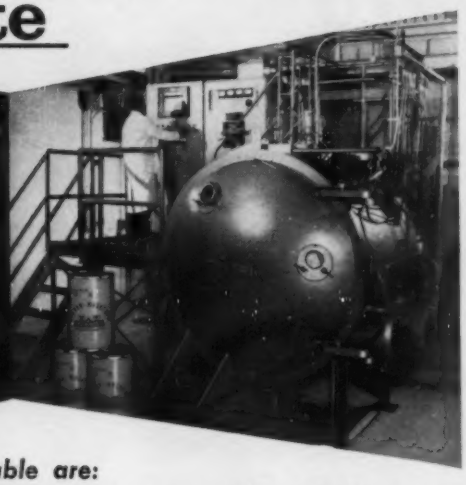
Sales Offices

Chicago • Cleveland • Detroit • Houston • Los Angeles • New York • San Francisco • Tulsa

"Haynes" and "Hastelloy" are registered trade-marks of Union Carbide and Carbon Corporation.

Now...Cannon-Muskegon offers complete

VACUUM MELTING service and UltraMet alloys...



Now available are:

stainless, tool and die, magnetic steels— high-temperature, corrosion-resistant, expansion alloys — bearing steels — electrical and electronic alloys — special alloys

RIGHT NOW . . . Cannon-Muskegon provides you with a ready source of super-clean, superior strength alloys to meet complex metallurgical applications. Our completely equipped and expertly staffed vacuum melting facilities as well as chemical, physical and metallurgical laboratory can help you *find, test and produce* vacuum melted alloys for any application . . . in test or production quantities . . . with accurately predictable properties.

Ferrous, nickel and cobalt-base alloys are poured at pressures from 1 to 10 microns — resulting in extremely clean metals for smoother surfaces . . . greater tensile strength, ductility and wear life . . . and higher electrical and magnetic properties. Contact Cannon-Muskegon for facts.

We offer industry

- ***Materials for remelt*** — under conventional air melting, inert gas, vacuum.
- ***Casting development*** — includes research and experimental facilities for investment, shell mold, dry sand, and permanent mold castings.
- ***Ingots or cast billets*** — for rolling, forging or extruding in individual weights up to 250 pounds.

Finest laboratory and production equipment is used in our vacuum-melting operation . . . available to you. Let our metallurgical specialists help you solve your alloy problem.

For full particulars write for our New Bulletin on Vacuum-Melting and Air-Melting facilities, products and service.

ULTRA MET
VACUUM-MELTED ALLOYS
FOR INDUSTRY

CANNON-MUSKEGON CORPORATION

2879 Lincoln Street Muskegon, Michigan

METALLURGICAL SPECIALISTS

Personals . . .

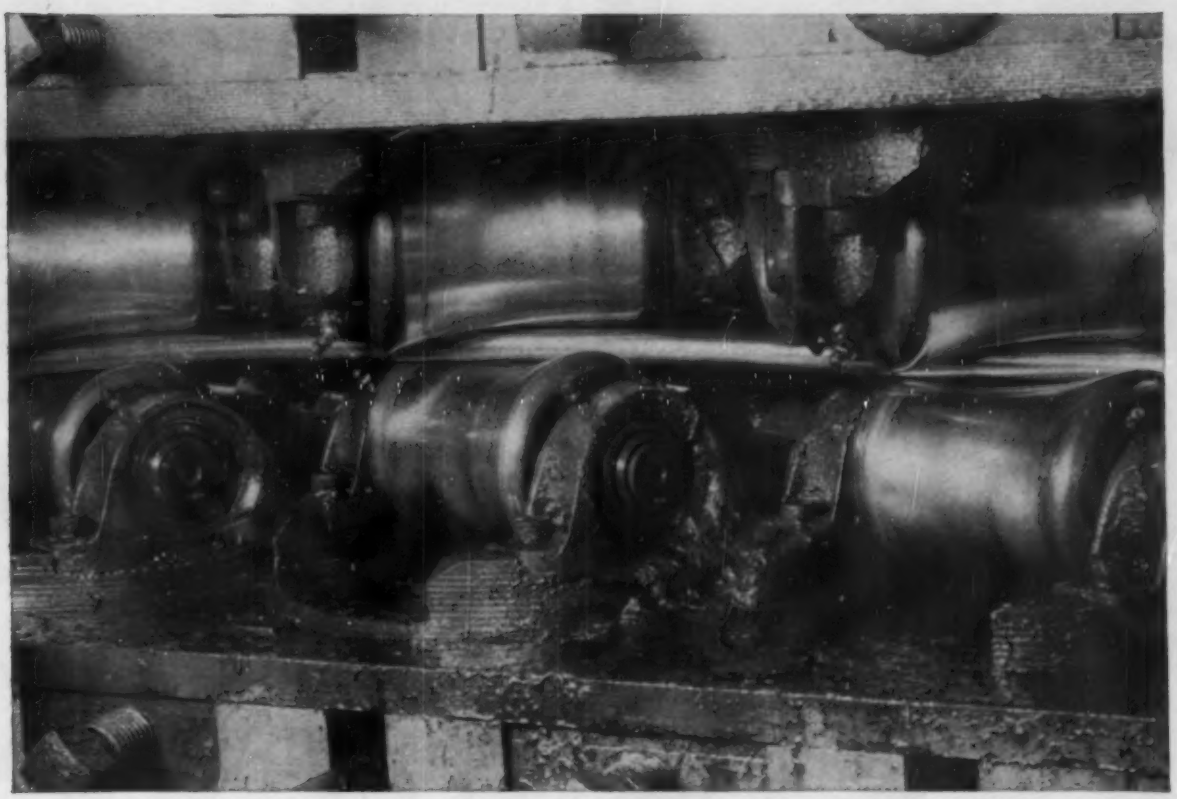
Donald R. Grandy has become affiliated with the Lindberg Engineering Co., Chicago, as engineering and technical consultant to the company's Cleveland division office. Mr. Grandy has represented industrial furnace manufacturers for over 20 years and is a specialist in high-frequency heating, nonferrous melting and field-erected heat treating furnaces.

Leo E. Gatzek was recently appointed supervisor of the heat treating department and plating and welding department at the Pacific Div., Bendix Aviation Corp., North Hollywood, Calif. In addition to his new duties, he will continue as head of the Bendix-Pacific Metallurgical Laboratory. Mr. Gatzek was a works metallurgist for Carrier Corp., Monrovia, Calif., before coming to Bendix.

Byron K. Elder and **Russell M. Kotys** have received new appointments in the metallurgical department of the Pittsburgh Steel Co., Pittsburgh. Mr. Elder, a resident service metallurgist with the company since 1955, has been named chief metallurgical engineer, service, with headquarters in Detroit, and will supervise all service metallurgy in the company's sheet, strip, wire and seamless mechanical tubing sales. Affiliated with Pittsburgh Steel since 1935, Mr. Kotys has been appointed a metallurgist for the sheet division at Allenport, Pa., assigned to quality control work on the hot mill. For the past two years, he has been a metallurgist in the Monessen Works' wire and rod mills.

Edward H. Perkins, Jr., was recently elected vice-president of Brooks & Perkins, Inc., Detroit. Mr. Perkins, a director of the company for the past two years, is manager of the Magplate Div. and administrative assistant to the executive vice-president.

S. Allen Oviatt has been named manager, special product sales, for Universal-Cyclops Steel Corp., Bridgeville, Pa. Mr. Oviatt had previously been manager of turbine blading sales, and will continue to be responsible for the sales of the turbine blading department.



Uses tool steel that outwears others 3 to 1 for its straightener rolls

TO help its customers get the longest possible life out of the rolls used in its small tube straighteners, Mackintosh-Hemphill Division of E. W. Bliss Co. makes them from Graph-Mo® steel.

Graph-Mo contains millions of tiny particles of diamond-hard carbides. As a result, users report it outwears other tool steels on an average of three to one!

Graph-Mo steel also contains free graphite which gives it outstanding anti-friction properties, prevents pick up and scoring. This is a big advantage to users of small Mack-Hemp straighteners because it results in a better surface on the products being processed. What's more it eliminates chrome plating the rolls, which is usually necessary when the straighteners are used for non-ferrous metals such as brass.

Graph-Mo steel gives Mackintosh-Hemphill two other important manufacturing advantages. It saves machining time because it's 30% easier to machine than ordinary tool steels. And it simplifies heat treating because of its uniform response to heat treatment.

Graph-Mo is one of four graphitic tool steels developed by the Timken Company. If you want more information about their use in dies, punches, gages and machine parts, write for the new Timken Graphitic Steel Data Book. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS TUBING

When you need 52100 steel bars and tubes go direct to Peterson....world's largest stocks. NOTE: For better machineability specify *leaded* bars.

52100

ONE WAY

PETERSON

STEELS, INC.

Union, New Jersey • Detroit, Michigan • Chicago, Illinois

Personals . . .

Joseph Daniels has returned to the United States after two years in West Pakistan establishing a department of mining engineering at Punjab College of Engineering and Technology in Lahore. He has resumed his status of professor emeritus at the University of Washington.

W. E. Ferguson has taken the post of metallurgist at the U.S. Naval Ordnance Test Station, China Lake, Calif. Previously, he was a materials and process analyst at Lockheed Aircraft Corp., Burbank, Calif.

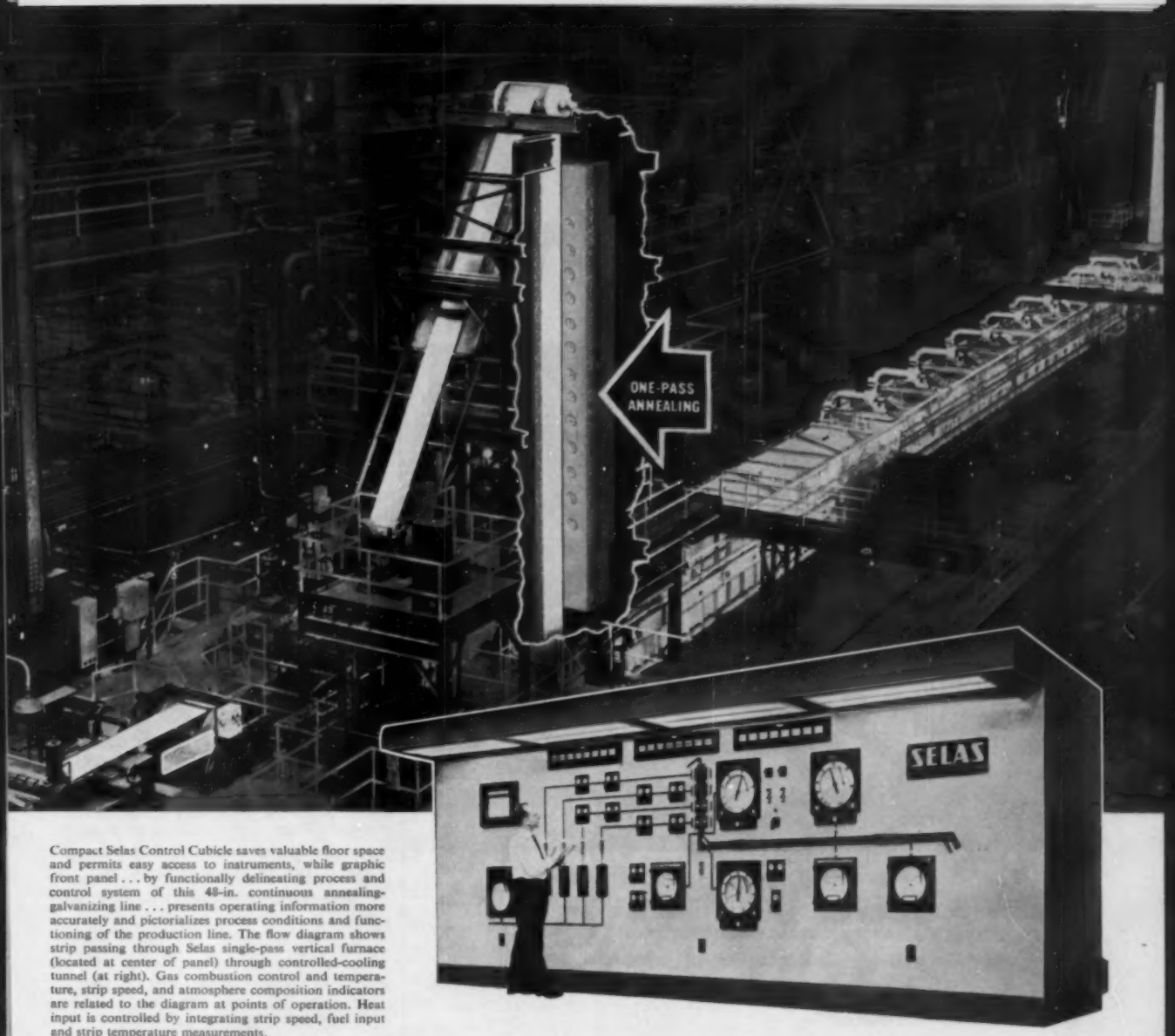
H. W. Schultze has accepted a position as assistant manager of chemical development with the Climax Molybdenum Co., New York. Until recently, Dr. Schultze was on the staff of the product and process development department of Electro Metallurgical Co., a division of Union Carbon and Carbide, New York.

Henry A. Thebom recently joined the National Cylinder Gas Co. in the Buffalo district as sales-serviceman. He was formerly associated with Linde Air Products Co.

John F. Tyrrell has joined Beaumont, Heller & Sperling, Inc., Reading, Pa., advertising agency, as account manager and technical consultant. Mr. Tyrrell formerly was associate editor of **Metal Progress**, and prior to that was New York district sales manager for the magazine.

J. L. Mauthe has been elected chairman of the board of Youngstown Sheet and Tube Co., Youngstown, Ohio. Since joining the company in 1935, Mr. Mauthe has served as assistant general superintendent of the Youngstown district, general superintendent, vice-president in charge of operations, and company director. In 1950 he was named president of the organization.

Richard M. Mandle is now technical director of the rare earths operation of the Davison Chemical Co. Div. of W. R. Grace & Co., Baltimore, Md. Until recently Mr. Mandle was a vice-president of Rare Earths Inc., formerly an affiliate of the company and now merged with the Davison Chemical Div.



Compact Selas Control Cubicle saves valuable floor space and permits easy access to instruments, while graphic front panel . . . by functionally delineating process and control system of this 48-in. continuous annealing-galvanizing line . . . presents operating information more accurately and pictorializes process conditions and functioning of the production line. The flow diagram shows strip passing through Selas single-pass vertical furnace (located at center of panel) through controlled-cooling tunnel (at right). Gas combustion control and temperature, strip speed, and atmosphere composition indicators are related to the diagram at points of operation. Heat input is controlled by integrating strip speed, fuel input and strip temperature measurements.

Controlled Strip Heating with Selas Gradiation® Processing

Steel strip is delivered continuously to the galvanizing bath, fully annealed and at temperature conditions best suited to the production of highest quality galvanized sheet . . . by the combination of Selas process control and Selas Gradiation heating.

The control cubicle, by visually relating the instrumentation to the processing flow diagram, simplifies process control and pictorializes functioning of the production line.

The Selas direct-fired heating principle is used in other continuous strip applications, including:

Bright annealing of steel . . . stainless steel annealing . . . tin reflow . . . galvanizing-annealing . . . preheat for galvanizing . . . preheat for annealing . . . bluing . . . special coatings . . . brass annealing.

In all these operations, radiant gas heat, precisely applied across the strip width, increases heating speed and produces unsurpassed uniformity in product quality.

- Compact single-vertical-pass design saves valuable floor space . . . avoids rolls in heated section, eliminating accompanying maintenance and product quality difficulties.
- Elimination of externally-prepared atmosphere in heating section reduces operating costs.
- Precise thermal control assures reproducible uniformity, regardless of gauge variations.

The same benefits are also being achieved in continuous annealing of nonferrous metals.

Our engineers will be glad to discuss how Selas Gradiation methods can be tailored to your strip heat-processing needs. Address Dept. 32.

SELAS
CORPORATION OF AMERICA
DRESHER, PENNSYLVANIA

Heat and Fluid Processing Engineers

DEVELOPMENT • DESIGN • CONSTRUCTION

Do you hear meaningless claims when you buy self-aging Aluminum Alloys?

Federated Tenzaloy is the most widely used of all high-strength, self-aging aluminum alloys because it has the highest yield strength, and it has the best all-around combination of properties. Yield strength is the true measure of a metal's ability to take punishment, regardless of other claims that are made.

When you buy Federated Tenzaloy, you can be sure it will perform as well as its specifications indicate. Tenzaloy is produced under the supervision of ASARCO's Central Research Laboratory, where refining and testing techniques control impurities to parts per million, if required.

Hundreds of foundries and manufacturers use Tenzaloy where heat treating is impractical because of casting design or size. Hundreds more cast Tenzaloy because heat treating facilities are not available.

Why not ask your Federated field man to tell you who uses this metal and how? He will be around to see you soon, and it will benefit you to talk to him.

Federated Metals ASARCO

Division of

AMERICAN SMELTING AND REFINING COMPANY

120 BROADWAY, NEW YORK 5, N. Y.

Personals . . .

Robert E. Buckholdt has joined the Selas Corp. of America, Dresher, Pa., as manager of engineering. Mr. Buckholdt, who has been active in the furnace industry for 23 years, will be responsible for Selas furnace and oven designs and engineering applications as related to industry. Before coming to Selas he was vice-president of Kendall Contracting, Inc., Alliance, Ohio.

C. L. Richards, an employee of Adirondack Foundries and Steel, Inc., Watervliet, N.Y., for 35 years, has been elected vice-president in charge of metallurgy and research of the company.

William J. Armstrong, formerly employed by International Nickel Co., Huntington, W.Va., is now on active duty with the U.S. Army, as a student in the surface-to-air missile section of the AAA & GM School at Fort Bliss, Tex.

Richard H. Schoemann has recently been appointed standards engineer in the materials and processes section of the standards engineering department at Sperry Gyroscope Co., a division of Sperry Rand Corp., Great Neck, N.Y. Prior to this appointment, Mr. Schoemann was a metallurgical engineer for the Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J.

William L. Bruckart, formerly a development engineer in the technical department of Universal-Cyclops Steel Corp., Bridgeville, Pa., has been transferred to the special product sales department. Mr. Bruckart's work in the development of molybdenum metal and refractory alloys will be integrated with other special product sales development.

R. B. Corbett has assumed new duties as director of metallurgy of the Midvale-Heppenstall Co., Philadelphia, a subsidiary of the Heppenstall Co., Pittsburgh. Dr. Corbett joined the parent company in 1945 as a research metallurgist and since that time has served as research engineer, director of research and assistant to the president (technical) of Heppenstall. He will continue to serve as a consultant to the Heppenstall Co.

Simplest pneumatic controller to use and maintain

Bristol gives you improved stability of control action –but keeps basic simplicity of Series 500 Controllers

Bristol Series 500 Pneumatic Controllers are the easiest controllers on the market to use and maintain–still the most dependable and trouble-free.

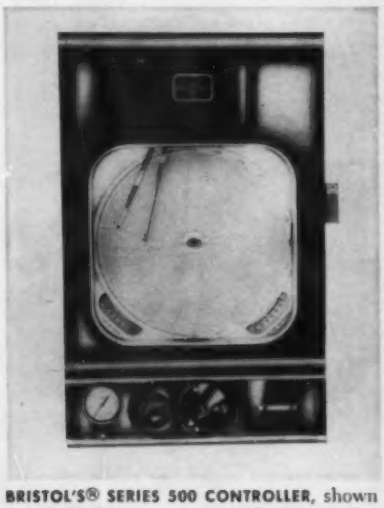
The reason? The basic simplicity of the operating mechanism. *That* hasn't changed in the years since we introduced this long-time favorite among instrument men. Reason No. 2: they are equipped with famous Bristol measuring elements.

Easy calibration

It's this foolproof simplicity of the control system that makes calibration so easy on Series 500 controllers. *Only one* service adjustment is required and provided to exactly calibrate the control system. The control system can be completely disassembled and after reassembly (even with replacement of parts) can be restored to precise calibration with this *one* adjustment.

No special tools are required. A ¼-inch wrench is all that's needed.

The 500's completely interchangeable parts, accurately designed and manufactured to extremely close tolerances, make possible this built-in calibration.



BRISTOL'S® SERIES 500 CONTROLLER, shown here with four-position transfer station. Internal station also available.

And check these features:

Improved control stability—advanced automatic control techniques have been applied by Bristol engineers to improve stability of control action in the new Series 500W Controllers.

Wide-band models offer choice of ½ to 400% proportional band with simple band shift.

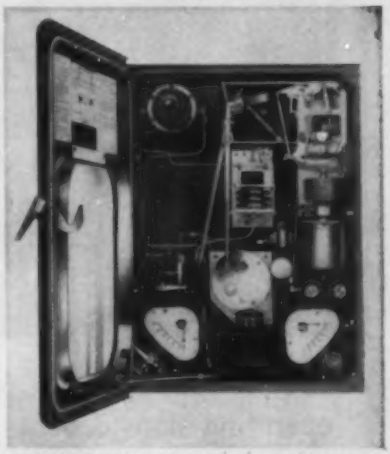
True zero derivative setting—exclusive with Bristol.

Reset action stops in reset models—again a Bristol exclusive—prevent loss of control due to prolonged deviation from set point.

Four-position internal transfer station with automatic, manual, test, and service positions, plus pressure-matching button and manual pressure regulator, for maximum convenience in process control.

Complete data available

Write today for engineering data on Bristol's Series 500 controllers for your critical control problems. They're available for *automatic control of temperature, pressure, vacuum, draft, absolute pressure, liquid level, humidity, pH value, electrical measurements, and mechanical motion.* The Bristol Company, 106 Bristol Road, Waterbury 20, Conn.



FOUR-POSITION INTERNAL TRANSFER STATION shown here in interior view of Series 500 Controller. Permits remote manual control, testing and servicing without disconnecting instrument.

YOU CAN GET THESE CONTROL MODES:

1. **Fixed narrow band** (on-off)
2. **Proportional band**—½ to 100% and ½ to 30%.
3. **Reset with wide band**—rates 0.1 to 10 or 1 to 300 repeats per minute. Proportional band ½ to 400%.
4. **Derivative (rate)**—½ to 100% proportional band. Derivative time 0.2 to 20 min., plus zero derivative setting.
5. **Reset plus derivative**—proportional band and reset rate as in "reset" above. Derivative time as in "derivative" above.

YOU CAN HANDLE THESE CONTROL PROBLEMS:

1. Cascaded control 2. Selective control 3. Ratio control 4. Time-program control 5. Pneumatic transmission.

6.55

BRISTOL *TRAIL-BLAZERS IN PROCESS AUTOMATION*

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

an ACCO product

Wilson "Rockwell"* Hardness Testers

Tests with INCREASED SPEED... Accurately

Y Model Motorized Hardness Tester

Illuminated Dial Gauge

(1) Affords clear and easy reading. Readings are easily taken wherever your "Rockwell" Tester is located—whatever the lighting conditions of the room.

Indenter light (2) is directed towards the test area, making it easy to locate the exact area of test at all times.

Requires fewer operating steps... *Because*

IT'S MOTORIZED

• Here is the motorized operating procedure made possible by the new WILSON "Rockwell" Y Model Motorized Hardness Tester—

1 Place specimen upon anvil or table.

2 Elevate test piece into test position. (With the new Set-O-Matic Dial Gauge, the large pointer will then automatically point to zero.)

3 Tap depressor bar to apply Major Load. When Major Load is fully applied, the Motorized Mechanism takes over—completes the test cycle—removes the Major Load.

4 Read "Rockwell" Hardness Number. Then, lower elevating screw to remove test piece.

For complete information about the WILSON Y Model, or any others of the complete line of WILSON "Rockwell" Hardness Testers, write or call today. A WILSON hardness testing expert is available to consult on your specific requirement. **Trade mark registered*

Set-O-Matic Dial Gauge

The Set-O-Matic Dial Gauge increases the accuracy of the test, makes the test cycle shorter and increases the number of readings obtainable within a definite period of time.

ACCO

Wilson Mechanical Instrument Division
AMERICAN CHAIN & CABLE

230-F Park Avenue, New York 17, N. Y.

for Better Value

Personals . . .

Fred L. Raspe, previously associated with Globe Forge, Inc., Syracuse, N.Y., is now general superintendent of Phoenix Mfg. Co., Catasauqua, Pa.

Charles M. Burke has been transferred from the sales office of Reynolds Metals Co., Albany, N.Y., to New York City where he will act as industrial sales representative for the company in the Bronx and Westchester County areas.

Adolph O. Schaefer has joined the Pencoyd Steel & Forge Corp., Philadelphia, as president of the organization. Mr. Schaefer, a past president (1955) of the American Society for Metals, was formerly director of research of the Midvale-Heppenstall Co., Philadelphia. Before the merger of the Midvale Co. and Heppenstall Co., he was vice-president in charge of engineering and manufacturing for Midvale Co., Philadelphia, where he was employed for 34 years.

Ernest Nippes, director of welding research at Rensselaer Polytechnic Institute, has begun a new program of research for studies of the welding of Zircaloy 3, a zirconium alloy. The investigation is being sponsored by the atomic power division of Westinghouse Electric Corp., Pittsburgh, under a one-year contract.

Virgil Emler has been promoted to supervisor of the metallurgy and barrier department of Goodyear Atomic Corp., Portsmouth, Ohio. He was formerly a group leader in this department.

Robert S. Day has been named head of the metalworking industries market of Leeds & Northrup Co., Philadelphia. Associated with Leeds & Northrup since 1948, Mr. Day's last assignment was as sales engineer in the St. Louis office.

John R. Duffy has been appointed chief engineer of Lindberg Engineering Co., Chicago. In addition to directing activities of an expanded engineering department, Mr. Duffy will be responsible for the design of the company's complete line of heat treating furnace and high-vacuum heating equipment.

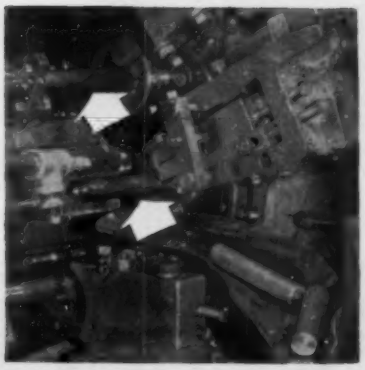
Studs for NELWELD process machined from Youngstown cold finished bars

Progressive fabricators rely on the Nelweld method for fast, dependable end-welding of studs to steel surfaces. This novel electric arc process—utilizing flux-filled steel studs—substantially reduces direct fastening costs when used to replace conventional time-consuming methods such as drilling, tapping, hard welding, through-bolting or the securing of straps and rivets.

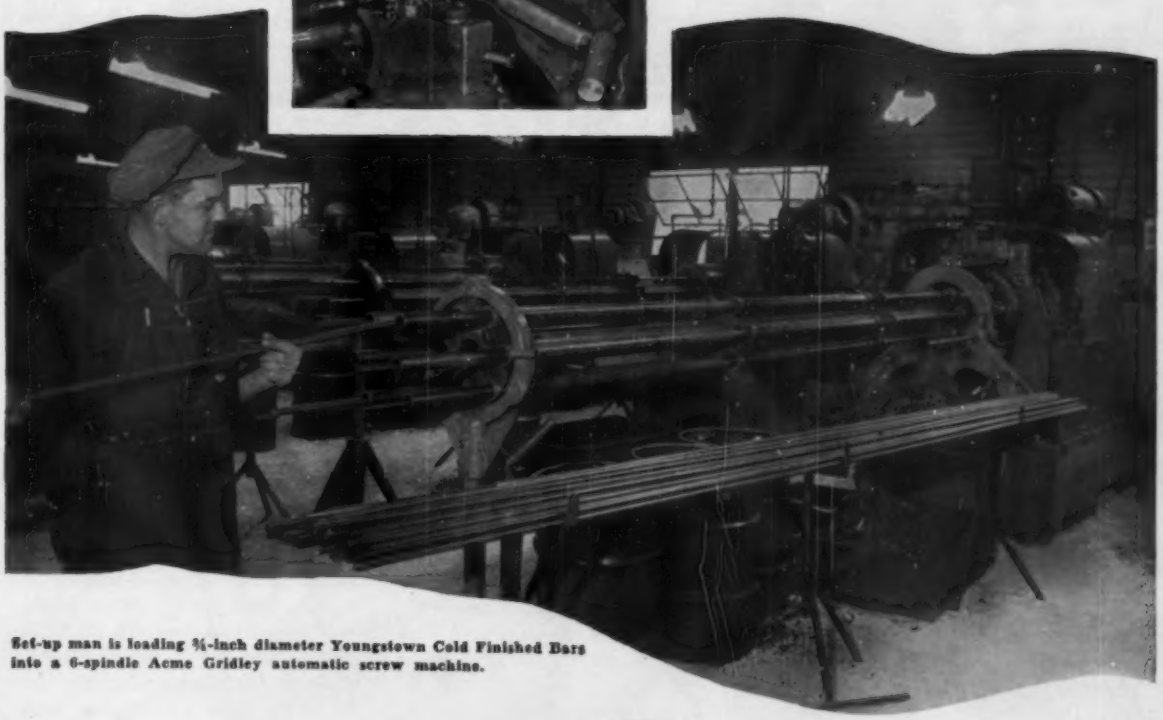
To maintain their world-wide reputation for product quality and uniformity, Nelson Stud Welding, a division of Gregory Industries, Inc., uses Youngstown Cold Finished Bars as the basic material for stud production.

Youngstown Cold Finished Bars provide high machinability and greater uniformity of composition, structure and surface finish to help you increase production of more uniform parts. Always specify Youngstown—it's your best assurance of quality.

Why not call or write your nearest Youngstown District Sales Office today for additional information or metallurgical assistance?



Close-up of studs being bored to accomodate their charge of flux (top collet) and then cut-off (center collet). Two finished Nelweld studs, shown in the pan in foreground, were machined simultaneously in the 6-position machine. First operation—feed out and face; second—bore; and third—cut-off.



Set-up man is loading ⅝-inch diameter Youngstown Cold Finished Bars into a 6-spindle Acme Gridley automatic screw machine.

THE YOUNGSTOWN SHEET AND TUBE COMPANY
Manufacturers of Carbon, Alloy and Yoloy Steel
General Offices - Youngstown 1, Ohio
District Sales Offices in Principal Cities

QUALITY YOUNGSTOWN SERVICE

Cold finished bars

Digests of Important Articles

Titanium From a Business Standpoint

Digest of "What the Future Holds for Titanium", by H. H. Kellogg, *Engineering and Mining Journal*, Vol. 156, April 1955, p. 72-84.

AN EXHAUSTIVE STUDY of titanium has been made to estimate its future prospects from a business standpoint. Many vexatious problems have arisen in connection with titanium, not only in technology to the producer and user, but also to the Government and businessmen in deciding whether production should be encouraged and promoted, and if so, by what means.

The titanium metal industry was barely six years old in 1955, but production in that year was estimated at 8000 tons, largely as a result of financial support by the Government. This was all made in the form of sponge by the Kroll process and sold at $3.95 to $5.00 per lb. Less costly processes may be developed in the future. The Government has been the only customer because titanium in military aircraft was believed to be essential for security of the nation, while commercial consumers got along without it because of the high price and uncertainties of supply. The present prices of the metal in various forms are not close to the minimum cost attainable with present methods of production, but have been much higher because of small volume, rapid amortization of plant, the high cost of research, development and technical help, and a large proportion of off-grade product for which no refining method is known. Most titanium has been rolled on mills designed for stainless steel, and the scrap produced cannot be readily utilized in subsequent production as with other metals.

When technological maturity is reached, with annual production of 200,000 tons in plants of 20,000 to 40,000 tons capacity per year, the following prices are predicted based on use of the Kroll production process and cold mold arc melting: $1.15 per lb. for sponge, $1.30 per lb. for ingots, and $2.09 per lb. average for mill products. These compare with 1955 prices of $3.95 per lb. for sponge, and $9.00 to $15.00 base per lb. for rolled metal.

Titanium ores are abundant and cheap. Rutile was favored in 1955 for metal manufacture, but in the future ilmenite will be preferred as more widely available and cheaper. The iron will first be removed by smelting, and the slag, containing about 80% TiO_2, will be mixed with carbon and chlorine to obtain $TiCl_4$. By using the chloride as the source of titanium for metal production, it is possible to obtain metal with acceptably low oxygen, nitrogen, carbon and hydrogen contents, all these elements being soluble in solid titanium and causing hardness and brittleness. To avoid contamination by these elements, the metal must always be produced and melted in a vacuum or an atmosphere of argon or helium. Molten titanium absorbs oxygen from all refractories and carbon from graphite, so pure ingots can be obtained only by arc melting the sponge in a cooled metal ingot mold. These inherent properties of titanium will always make its processing technique more expensive than those used for more familiar metals such as aluminum and magnesium.

Crude $TiCl_4$ must be carefully purified, and for best economy the chlorine should be recovered from any $FeCl_3$ formed. A continuous chlorinating plant including these features, and with automatic control, should be possible for large operations at a cost of $600 per annual ton of titanium, and should produce pure $TiCl_4$ for about 10¢ per lb.

It is assumed that the Kroll process of reducing $TiCl_4$ by magnesium in a closed reactor will be retained in the future, using larger batches and labor-saving devices such as improved sealing and cooling, and prevention of adherence of sponge to the reactor walls. Purification of the raw sponge will probably be done by leaching in large plants, relying on vacuum treatment in melting to remove hydrogen. About 75% of the $MgCl_2$ produced will be converted by electrolysis to magnesium and chlorine for re-use in the process. Assuming a future plant having a capacity of 30,000 tons of titanium sponge per year, the part for sponge production is estimated to cost $1600 per annual ton of capacity, and the part for $MgCl_2$ electrolysis $1000. Adding the estimate for the chlorination plant and a small amount for land, laboratory and office, the total investment required would be $104,000,000 for converting slag to sponge metal.

The cost estimates for sponge production in this future plant are tabulated in detail. The total arrived at per lb. of titanium is 72.5¢, composed of 18.6¢ for materials, 11.3¢ for electricity, fuel and water, 28¢ for labor, supplies and maintenance, and 14.6¢ for testing, administration, insurance and depreciation. For these calculations, it is assumed that 87% of the titanium in the slag chlorinated will be recovered as good sponge, and 1.0 lb. of chlorine and 0.3 lb. of magnesium would be lost per pound of titanium product. Other assumptions were 7 mils per kw-hr. for electricity, labor averaging $20 per man-day, and 10% of the investment per year for maintenance. No sales cost is included. A price of $1.15 per lb. for the sponge, with 52% paid for

This GIANT sleeps just once a year

-on Christmas Day

Built at a cost of $2,600,000 by Marion Power Shovel Company, *The Mountaineer* costs $1,000 an hour when idle. As a result, it just isn't permitted to be idle—except on Christmas Day. The rest of the year, it works 24 hours *every day* at the world's largest strip mine, owned by Hanna Coal Company.

Tough, durable USS "T-1" Steel in the dipper, dipper stick, bail and crowd rack helps *The Mountaineer* do more work than any other power shovel in all the world. This machine can pick up 90 tons of overburden in one bite, pile it 290 feet away, to a height of 100 feet, and swing back for another 90-ton load—all in just 45 seconds! Working at this rate, it can move 7 million yards of overburden a month.

And every yard is tough going. USS "T-1" Steel parts must ram through rock and earth, taking terrific impact and shock, even in the dead of winter. They hold up in this service because USS "T-1" Steel retains its amazing toughness at temperatures far below zero . . . and has excellent resistance to impact abrasion.

Weight was saved with USS "T-1" Steel too—a total of 40 tons!—because of its very high yield strength of 90,000 psi and its excellent weldability. In spite of the high strength, Marion had no difficulty welding, forming, and machining this high-quality alloy steel.

• • •

USS "T-1" Steel can help *you*. Consider it where you need high strength, extraordinary toughness, resistance to impact abrasion, or good creep rupture strength *combined* with ease of fabrication. We'll gladly help you adapt it to your particular problem. United States Steel, Pittsburgh 30, Pennsylvania.

USS "T-1" CONSTRUCTIONAL ALLOY STEEL

UNITED STATES STEEL

UNITED STATES STEEL CORPORATION, PITTSBURGH
COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA.
UNITED STATES STEEL SUPPLY DIVISION,
WAREHOUSE DISTRIBUTORS, COAST-TO-COAST
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS

"We forged 10-foot rings from a 5-foot ingot... in stainless steel"

says **John Matthews,**

U. S. Steel General Foreman—Forging

It required many days to take the photographs on this page, days of forging and re-heating. The forgings are made from type 304 stainless steel, and they're destined for a nuclear power plant. Now read why it took so long to make them.

Stainless is strong and stiff, even at forging temperatures. It requires more passes through the press, more die pressure, and the dies wear out faster. If you forge it too long, so that it gets "cold," it will develop small surface cracks beneath the great jaws of the press.

In John Matthews' words:

"We started with a 59" fluted ingot and forged it down to a 40" octagon, then sliced it into three flat discs. The thickest disc was forged down to 18", and we put a 23" hole through it with steel punches. Then it was worked over the big steel mandrel to finished size: 119" outside diameter, 80" inside diameter, 10½" thick. The other two rings were somewhat thinner."

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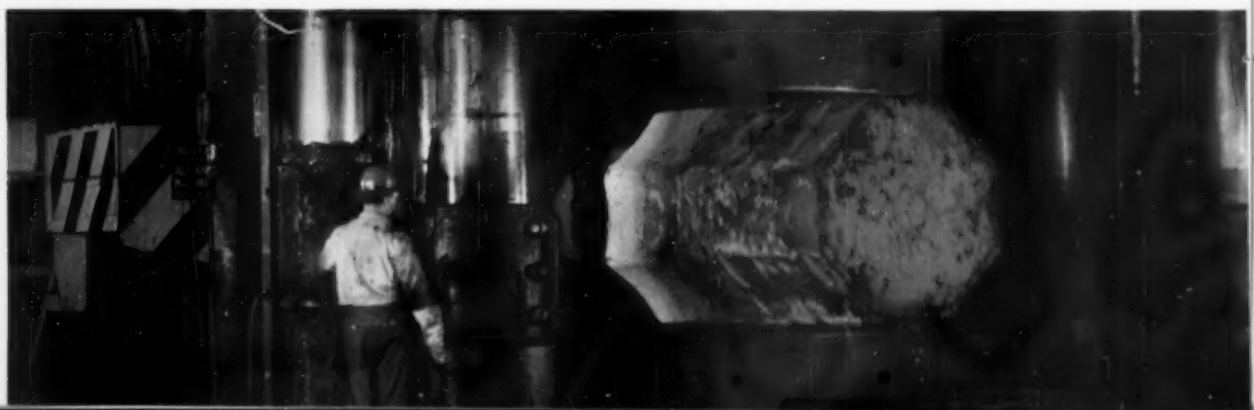
We'll certainly appreciate your inquiries. Send them, or requests for our free 32-page booklet on USS Quality Forgings to: United States Steel, Room 2801, 525 William Penn Place, Pittsburgh 30, Pa.



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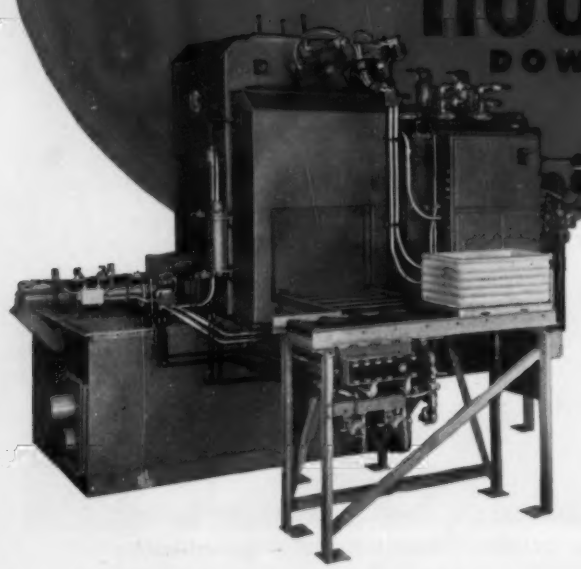

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Titanium . . .

income tax, is calculated as sufficient to repay the investment cost in less than 9 years.

To convert the sponge into ingots for rolling, it is first pressed to rod form, and the rods are used as electrodes which are melted down by arc inside a cooled ingot mold filled with argon. Any alloying elements, and up to 30% scrap for remelting, are incorporated with the sponge at this stage. Since only a small portion of the ingot is melted at any one time, segregation is excessive and must be reduced by remelting, using the first ingots as electrodes. Before and during fabrication by forging or rolling, surface defects must be removed mechanically. This process is assumed to be retained in the future plant making 30,000 tons of sponge per year. Using alloys, plant scrap and 10,200 lb. of purchased scrap per year to give a total of 59,300 tons melted, the rolled products recovered are estimated as 38,500 tons (65% recovery). It is assumed that a method for refining contaminated scrap will be invented, and that the future price of remelt scrap will be 70% of the price of sponge, or 80¢ per lb.

A plant for producing 55,000 tons of conditioned ingots per year in this way from sponge and scrap is estimated to cost $55,000,000. The ingot cost is calculated to be $1.16 per lb., made up of $1.01 for sponge, scrap and alloys, $0.02 for electricity and water, $0.083 for labor, maintenance and supplies, and $0.047 for miscellaneous other expenses. A price of $1.30 per lb. for ingots is considered adequate to pay the 52% income tax and amortize the investment in less than 8 years.

Forging and rolling costs are estimated by comparison with stainless steel, which titanium resembles in hot forming ability. The cost of scale and scrap losses, however, may be six times as great, and the volume capacity of a mill must be nearly double because of the density difference. Thus the fabrication cost could be taken as about four times that of stainless steel. Calculation on this basis from stainless steel prices leads to prices of $1.78 per lb. for titanium billets, $2.06 for plates, and $2.34 for sheets. A cost of $85,000,000 for a fabrication

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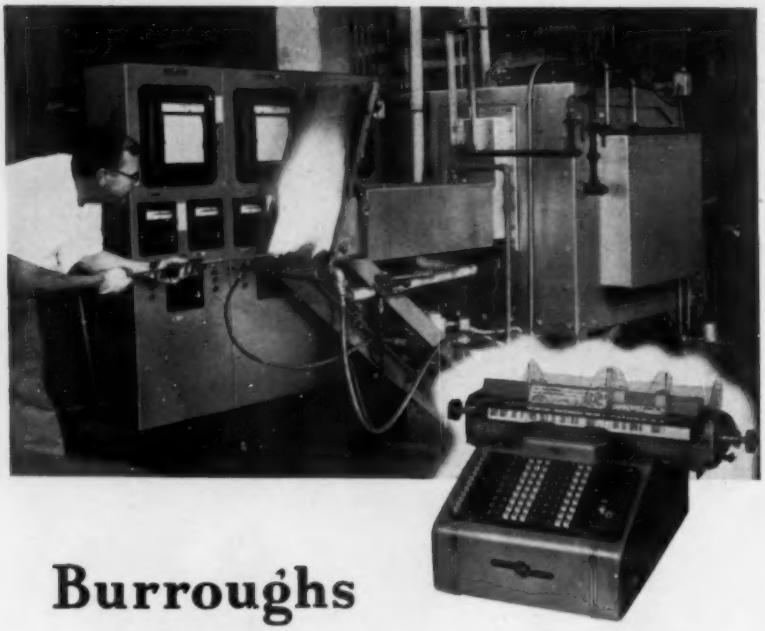

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4. Simple construction of furnace permits charging while at operating temperature.
5. Air operated doors enable operator to have both hands free when charging furnace.
6. Long element life saves maintenance costs, reduces down time.
7. Electric heating elements provide clean, safe heat.

To complete their tool room department, Burroughs uses; two Hevi-Duty Multi-Range Furnaces for hardening and annealing steels other than high speed; two Hevi-Duty Salt Pot Furnaces for drawing and tempering tool steel; a Hevi-Duty Box Air Draw Furnace for drawing all steels; and a Hevi-Duty Pot Furnace for local hardening.

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Titanium . . .

plant delivering 38,500 tons of rolled products per year is claimed to be justified by these prices.

The lowest costs achieved in present practice are far above those predicted here for a large future plant, because of various unsolved production problems and small-scale operations. But development of improved processes may make even these estimates too high.

Titanium will never be as cheap as aluminum or stainless steel. It will, however, always be in demand for use in movable structures because of its high strength-weight ratio, which in the annealed state (alloyed) is equivalent to that of the strongest heat treated aluminum alloy, and over 50% higher than that of stainless steel. It can be used 400° F. hotter than the maximum service temperature of aluminum alloys, and has superior resistance to corrosion in many applications. Consumption of 200,000 tons per year in the United States is predicted when the base prices fall to $2.00 to $2.35 per lb. for plates and sheets.

G. F. COMSTOCK

Brittle Fracture of Heavy Sections

Digest of "Problems and Progress in Manufacture and Metallurgy", by H. H. Burton, *Journal* of the Iron and Steel Institute, Vol. 183, June 1956, p. 113-123.

THIS PAPER, the presidential address of the Iron and Steel Institute, gives an English viewpoint on the problems facing metallurgists in the melting, fabrication and heat treatment of steel as a result of the increasingly critical demands for better quality components used in engineering construction. Specifically, the needs of the shipbuilding, power generating, and aircraft manufacturing industries are outlined and many of the difficulties of processing very heavy forgings (over 50 tons) are described.

The author first discusses the dilemma of the shipbuilders which has arisen because of the change from riveted to welded construction. The spectacular "brittle fractures" of ship plates are largely associated

with locked-up stresses in welded assemblies. He states, "To meet the new needs of welded construction, killed steel, having a composition which is almost within the alloy steel category, with controlled grain size, is likely to be necessary and the possibility of heat treatment, never before applied to large plates, is looming nearer and nearer."

In the power generating field, problems relating to the production of heavy forgings, such as turbine and generator shafts and hollow forged boiler drums having walls more than 5 in. thick, are reviewed. The need for greater care in cooling and preheating large ingots of alloy steel is compared to the simpler operations which are adequate for smaller steel sections. Because of composition and size, large forgings are highly susceptible to hairline cracks, internal flakes and lines of segregation. The prevention of these defects is difficult. Proper heat treatment after forging operations often extends over hundreds of hours. Most of the discussion seems to be based on a 3% Cr-Mo steel. No mention is made of the role of hydrogen in steel embrittlement, nor does the author consider the equally difficult problem of alloy selection for superheater tubing and steam pipe at pressures above 3000 psi. and temperatures above 1100° F.

The demands of aircraft engineers for weight reduction by the use of alloy steels, heat treated to tensile strengths of 200,000 to 275,000 psi., poses a problem since the fatigue strength of such steels does not increase in proportion to the increase in tensile strength. Tests show that alloy steels of 190,000 psi. have the same fatigue strength as steel heat treated to 225,000 psi. Quoting extensively from Iron and Steel Institute Special Report No. 50, 1954, the author summarizes this situation as follows:

1. Fatigue strength does not increase in relation to tensile strength.
2. The "cleanest" steels are not always the best in fatigue tests.
3. Silicate inclusions are more damaging to fatigue strength than sulphide inclusions.
4. There is no correlation between the notched-bar impact tests and fatigue tests.

The remainder of the address deals almost entirely with steel melting methods, heating cycles during

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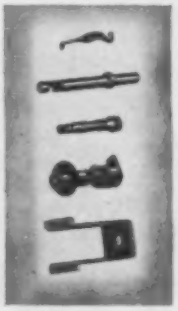

These parts from the Argus C-3 and C-4 color slide cameras are typical of the parts treated in the above Hevi-Duty Shaker Hearth Furnace.

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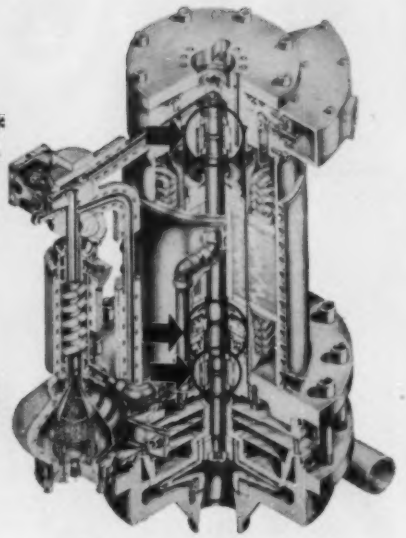

Bearings and thrust runners operate perfectly after 2000 hours handling sodium, NaK and other metals at 1050°F and above

Cut-away view of Westinghouse pump to handle liquid sodium, NaK or other metals at temperatures up to 1500°F. Circles show bearings and thrust runners of Kennametal and Kentanium, which meet the most rigid specifications of tolerances and quality of material to provide *continuous, 100% leak-proof pumping operation for extended periods.*

Kennametal and Kentanium are sharing in one of the engineering advancements of the year . . . the Westinghouse centrifugal liquid metal pump designed for the atomic power industry. Kennametal grade K9** and Kentanium K138A** were selected for the vital bearing and thrust runner parts which are lubricated by liquid metal with a film much thinner than oil lubricants. Surfaces must not corrode and must be highly wear resistant to maintain leak-proof seals . . . rugged requirements which Kennametal and Kentanium have met under gruelling tests.

RUGGED ENDURANCE TEST: After 500 hours of operation with the pump stream at 1050°F (and 120 psi head), the pump was taken down and the Kennametal and Kentanium parts examined. They showed no change. Now, after 2000 hours of around-the-clock operation, these parts continue operation in apparent perfect condition. Larger Westinghouse pumps now being built to handle sodium and NaK at 4000 gpm and 1500°F at 250 psi pump head include similar parts of Kennametal and Kentanium.

These applications suggest the use of Kennametal or Kentanium wherever two surfaces rub together or are forced together . . . especially under severe conditions as encountered in handling liquid metals or other difficult-to-handle materials. Such applications might include valve seats, rings, bushings, sleeves on shafts, etc. Kennametal engineers are prepared to assist you. They have years of accumulated experience in the development of hard carbide metals to meet special requirements. Call or write KENNAMETAL INC., Latrobe, Pennsylvania.

*Trademarks of a series of sintered tungsten and titanium carbides.

**Approved, Bureau of Ships Specification, Carbide Stocks for Bearings, MIL-C-18482, 20/4/55.

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Brittle Fracture . . .

forging, and final heat treatment in the processing of heavy forgings.

The author favors the use of acid steel for heavy forgings due to its lower hydrogen content, greater fatigue strength and much lower susceptibility to damage when overheated. The application of the new Bochum vacuum casting process for the reduction of gases in the ingot is advocated, even though this practice contributes nothing to the segregation problem. The present furnaces and forging equipment in England are said to be inadequate for handling heavy forgings and the author states there is a need for heavier presses and larger furnaces with improved temperature control. Double tempering at 1340° F. followed by retempering at 1110° F. showed much higher V-notch values at room temperature and also a much lower transition temperature (−76° F.) for one type of steel.

Methods of improving the properties of heavy alloy steel forgings which the author recommends, include:

1. Further investigations of the effects of temperature and casting rate, employing the widest possible range in both these variables.

2. More laboratory work to determine the effect on segregation of different rates of cooling through the freezing range.

3. Study of steel melted in a vacuum under the same conditions that apply to the second recommendation.

4. More thorough investigation of effect of working temperature on the quality of the product, using specimens which have (*a*) transformed and (*b*) not transformed during the interval between stripping from the mold and reheating.

Both laboratory and production-size experiments are visualized, which include (*a*) investigation of efficacy of various heat treatment cycles in prevention of hairline cracks in steels of different composition, (*b*) consideration of the possibilities of unconventional heat treatment such as austempering and martempering, and (*c*) investigation of cycles involving heating into the transformation temperature range at some stage in the cycle.

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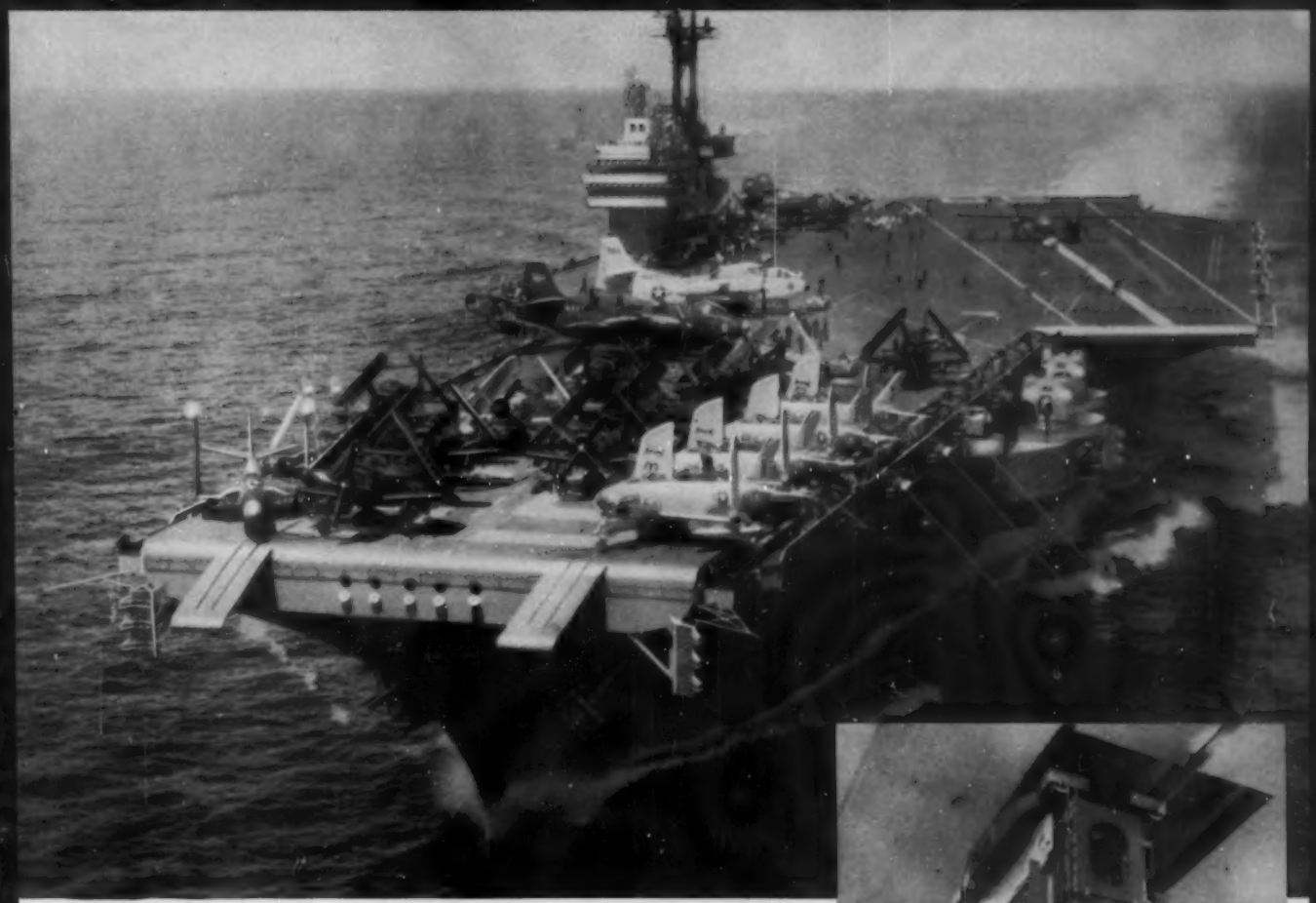
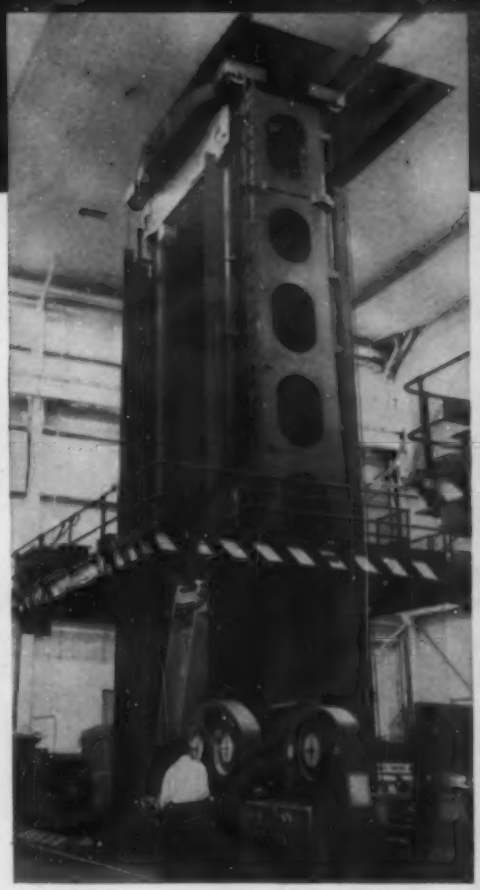


Official Navy photograph



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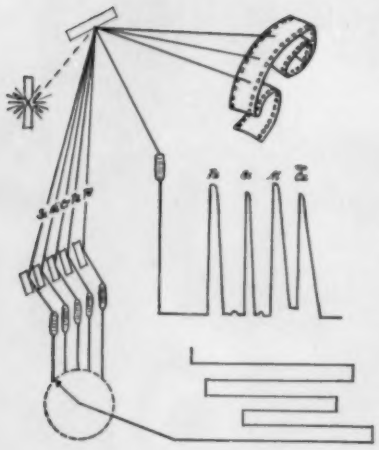

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Adding Aluminum to Steel Weld Metal

Digest of "The Effect of Aluminum Additions to Mild Steel Weld Metal", by Craig G. Sibley, *Welding Journal*, Vol. 35, August 1956, p. 361s-368s.

THE BARE and copper-flashed steel electrodes currently used in gas-shielded welding processes are usually deoxidized with silicon or aluminum, or both, and the finished wire generally contains a generous amount of residual deoxidizers, yet occasionally weld metal porosity is encountered which is attributed to lack of available deoxidizers. The author states that a particular aluminum-coated steel wire eliminates or controls such porosity. Its other good effects are (*a*) reduction of weld metal fluidity caused by an aluminum oxide skin on the weld metal surface which prevents melting and (b) good corrosion resistance of the wire during storage.

Various aluminum coatings were applied to mild steel core wire of welding quality by hot dipping, and the effects of these coatings on welding characteristics and properties of the weld metal were reported.

The core wire was of the following composition: 0.12% C, 0.63% Mn, 0.027% P, 0.020% S, 0.45% Si, 0.004% Ti, 0.13% Al + Al_2O_3. This wire was used as coated and in bright bare finish as a reference electrode. The coatings were:

No.	Coating	Oz. per Sq.Ft.
1	None	—
2	3% Si	0.19
3	3% Si	0.21
4	Al	0.22
5b	3% Si	0.21

Bead welds were deposited on 0.5-in. plates of rimmed and killed steel with oxidized, sand-blasted or ground surfaces. Killed steel plates 0.75 in. thick also were used with surfaces coated with iron oxide, paint or grease. Reverse polarity, d-c. current of 420 to 440 amp., and pure argon shielding were used. The beads were radiographed to 2% sensitivity and the number of holes counted. Typical beads were cross-sectioned and etched to determine uniformity and undercutting. Plug welds were also made (in argon) to fill a 1.5-in. hole drilled in a 1.5-in. plate with a steel backing.

All-weld-metal specimens (0.505-

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Original specifications called for only 12,000-lb. tray loads, but operating schedules have imposed 50,000-lb. loads, with each tray also required to *pull* two other loaded units through the furnace. Size of trays: 20' 10" long x 18" wide. Material: Stainless Steel. Temperature: 1500° F. Rolock Serpentine articulated construction permits required expansion and contraction, assures maximum service life.

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6RL56

Weld Metal . . .

in. bars) for tensile testing were made with each electrode in 1-in. plate, and tested either as-welded or stress-relieved at 1150° F. for 1 hr. Transverse Charpy-type impact specimens were machined from each deposit with an Izod notch centered in the weld metal.

Despite wide variations in the surface conditions, variations in porosity were only minor. Only Electrode 2 varied significantly from the uncoated Electrode 1. Statistical treatment of the data indicated (*a*) a significant variation in porosity between bare and aluminum-coated electrodes, (*b*) between cleaned and scaled surfaces, and (*c*) between bare and coated electrodes only on scaled plates.

Undercutting is affected by the arc action on the plate surface and the weldability of the weld metal. Pronounced undercutting occurs with aluminum-coated electrodes at 10 in. per min., indicating that the slag increases the surface tension of the weld metal. At 30 in. per min., undercutting occurs on all uncleaned surfaces.

Electrode 1 had the best ductility, and the coating reduced ductility and yield strength. Stress-relief reduced the tensile and yield strengths and increased the ductility. CO_2 shielding increased the as-welded ductility above that obtained for argon.

There were pronounced variations in microstructures depending upon the amount of metallic aluminum in the deposits. Deposits containing the most aluminum have coarse dendritic grains. Each multipass weld contained layers of coarse and fine grains, and the aluminum widened the coarse-grained regions. Impact testing resulted in such variations as might be expected from the microstructural variations; stress-relieving did not help, nor did CO_2 shielding. The data indicate that 1.06 to 1.65% aluminum in the weld metal shifts the impact transition toward higher temperatures, and that small changes of aluminum content within this range result in sharp variations in transition temperatures.

In plug welding the use of aluminum-coated electrodes sharply reduces porosity, resulting from the formation of aluminum nitride

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- Calibrated polarizing apparatus, 5 filters, dustcover, cabinet, etc. all included.
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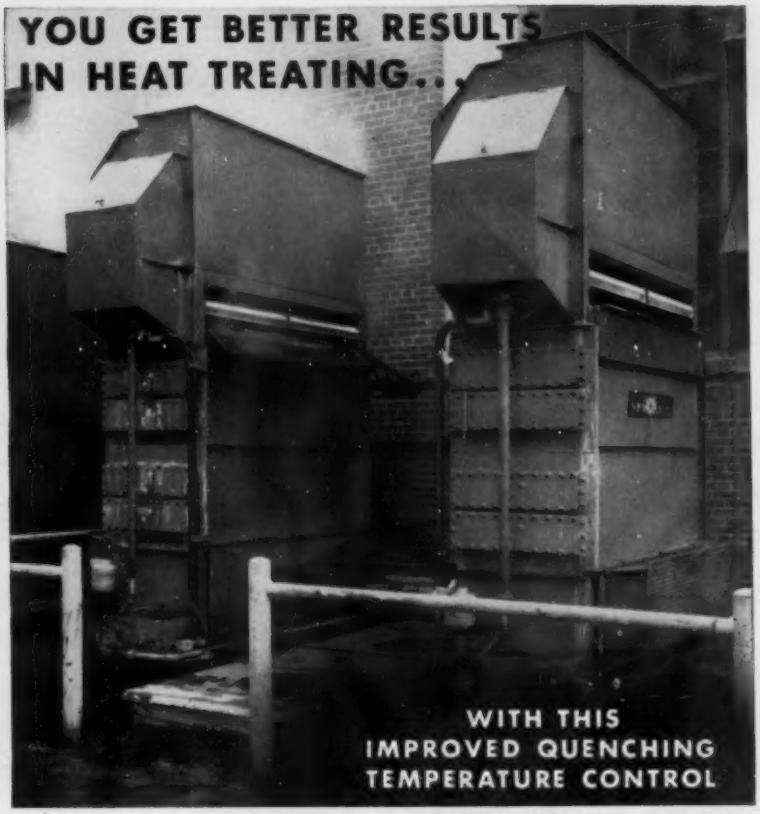

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Weld Metal . . .

(which prevents nitrogen porosity). However, nitrogen in steel, whether in gas or combined form, generally affects its mechanical properties adversely.

For both bead and multipass welds, porosity is generally less where CO_2 is the shielding gas than for welds made with argon.

H. J. NICHOLS

A Mobile Atomic Power Unit

Digest of "Packaged Atomic Power", by W. D. Leggett, Jr., *Ordnance*, May-June 1956, p. 968-971.

A TRANSPORTABLE OUTFIT for providing usable power from atomic fission is being constructed for the army at Fort Belvoir, Va. It is called a "package power reactor" because its component parts can be divided into units small enough to be carried in an airplane for assembly at a remote location where it would be very costly to provide coal or fuel oil for power generation by conventional methods. A two-year supply of nuclear fuel is included in the package, replacing about 1000 fueling flights that would be required for the same power produced by combustion.

The present construction was started in October 1955, and the plant should be ready for operation early in 1957. The reactor pressure vessel (material and wall thickness not given) will be 4 ft. in diameter and about 8½ ft. tall. It will house the core which will be cooled by water under 1200 lb. pressure, entering at the bottom of the vessel at 431° F., leaving the top at 450° F., and flowing at the rate of 4000 gal. per min. This water will pass to a steam generator where its heat will form 34,400 lb. of steam per hr. at 200 lb. pressure and 407° F. for a turbine driving a 2000-kw. electric generator.

The reactor core will be about 20 in. square and 30 in. tall, the uranium being packed in 40 stainless steel cases 2¾ in. square and 36 in. long, although the active length is 22 in. Five control rods will be located symmetrically among the

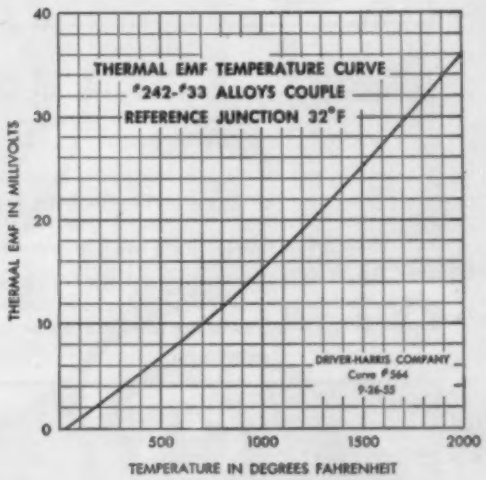
Driver-Harris Announces Major Advance in Pyrometry!

New #242-33 Thermocouple* for Reducing Atmospheres Maintains Calibration Through a Greatly Extended Life

This new Driver-Harris Thermocouple was developed primarily to withstand industrial reducing atmospheres at high temperatures and thereby to end the danger of runaway furnaces and ruined charges.

Unusually high resistance to "green-rot" attack is the outstanding property of the alloys of this thermocouple, whose analysis is:

Positive Leg (No. 242 Alloy)	Negative Leg (No. 33 Alloy)
80/20 Ni-Cr + Cb	3% Si-Ni



Although the thermal-emf response of this thermocouple is lower than the conventional thermocouple now in use, the slope of its temperature-emf curve is virtually parallel in the higher ranges of temperature in which both couples are designed to be used. Thus, the thermal-emf sensitivities are equivalent in the higher temperature ranges.

Tested against the conventional thermocouple in an atmosphere of the following nominal composition: CO...10%; CO_2...5%; CH_4...1%; H_2...16%; O_2...Nil; N_2...Balance (best for accelerating green-rot attack), exposure after 212 hours showed *only +0.13 mv. drift for the D-H thermocouple, and −7.54 mv. for the conventional thermocouple.*

When the thermal-emf of the conventional thermocouple *drops*, as in a reducing atmosphere such as this, the working temperature of the furnace controlled by it *rises*. However, when a #242-33 couple is used under the same conditions the thermal-emf remains substantially constant. This means that a furnace controlled with the new D-H thermocouple *cannot overheat and ruin charges.*

Members of the Heat-Treating and Instrument Manufacturing Industries are urged to investigate this new Driver-Harris Thermocouple without delay so that through their combined efforts all U. S. Industry can benefit. Complete technical data and application information is waiting for your inquiry. Write today to our Thermocouple Division.

*U. S. Patent No. 2,691,690

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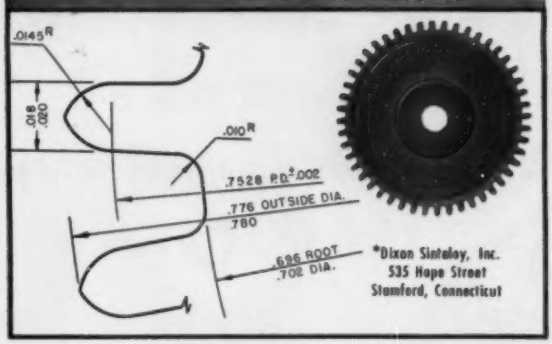

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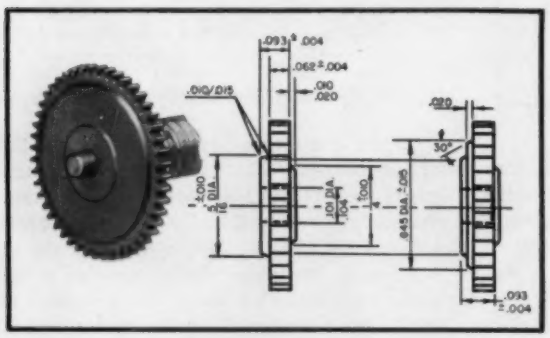

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Atomic Power . . .

fuel elements, and these will be controlled by means of motor-driven shafts and gears beneath the reactor. The control rods will be hollow, with removable fuel and absorber portions. Adequate seals will be provided to prevent leakage of radioactive water around the control shafts, and a universal joint next to the driving motor will allow for uneven thermal expansion.

The reactor pressure vessel will be surrounded by a primary shield consisting of eight layers of iron 2 in. thick in a water tank 47 in. thick radially. This would give more than adequate radiological safety for a remote location. At Fort Belvoir, which is close to Washington, D.C., additional safety will be provided by enclosing the package power reactor inside a ⅞-in. thick steel bell, 64 ft. tall and 36 ft. in diameter, covered with 2 ft. of concrete. This will insure against any accidental leakage of radioactive vapor. When fuel elements have to be replaced, they will be kept submerged in at least 12 ft. of water for radiological safety.

Nuclear package power plants should be useful in devastated areas as well as at remote military bases. Civilian use in areas where combustible fuel is expensive, or for nuclear research, may also be economically justifiable.

The actual cost of this package power reactor is not yet known because construction is incomplete, but the contract for the construction was awarded by the A.E.C. at a fixed price (not stated in the article), and a discussion of costs is offered. For a larger plant such as is being built at Shippingport, Pa., for the Duquesne Light Co., a total cost of 14 mils per kw-hr. was predicted. Actual costs have ranged from 39 to 52 mils per kw-hr. "for the first development stages". The contractor for the smaller packaged plant is "striving toward a figure of 18 mils per kw-hr." This is not considered too high for many areas where conventional fuels are expensive, especially where air transport is required, since the cost of supplying fuel in that way may amount to as much as 23 mils per kw-hr. for a 1500-mile flight.

G. F. Comstock

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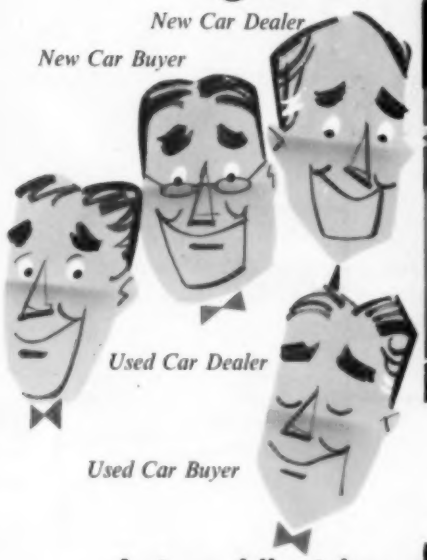

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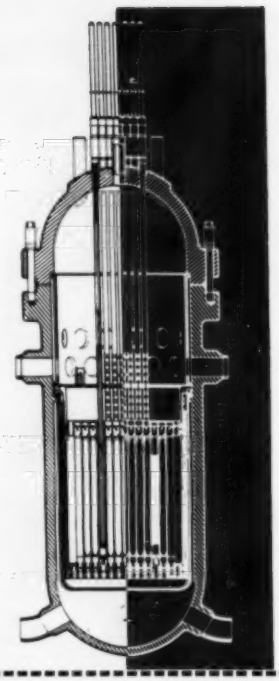

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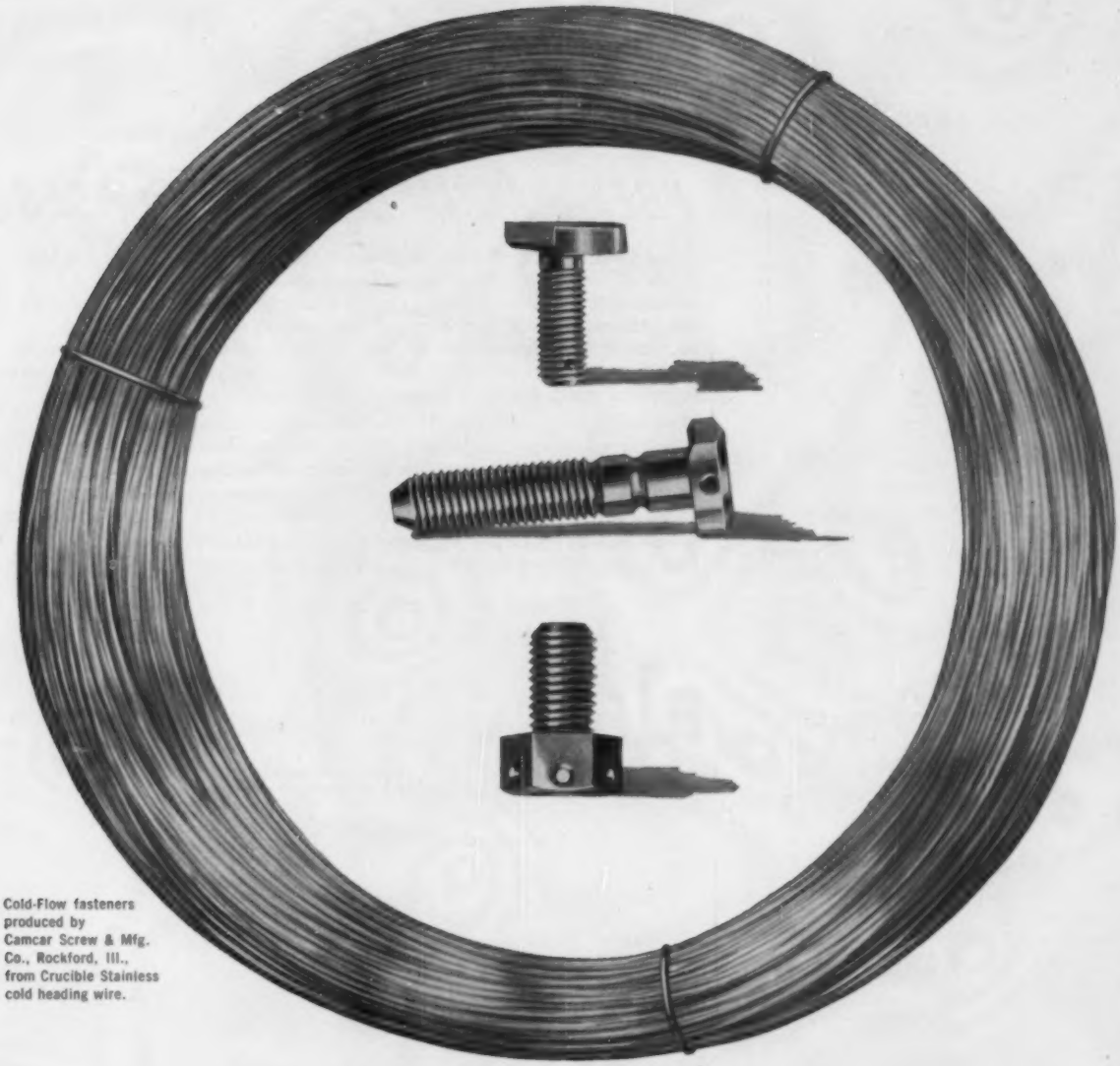

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Obviously, preparation of RaLa sources is done entirely with remote-handling equipment largely controlled with pushbuttons and actuated through servo-mechanisms. Design and much of the fabrication of the handling apparatus are also Los Alamos accomplishments and the Laboratory facility is one of the most highly developed in the United States.

Scientists and engineers interested in these or other projects at Los Alamos Scientific Laboratory are invited to write to:

Director of Scientific Personnel
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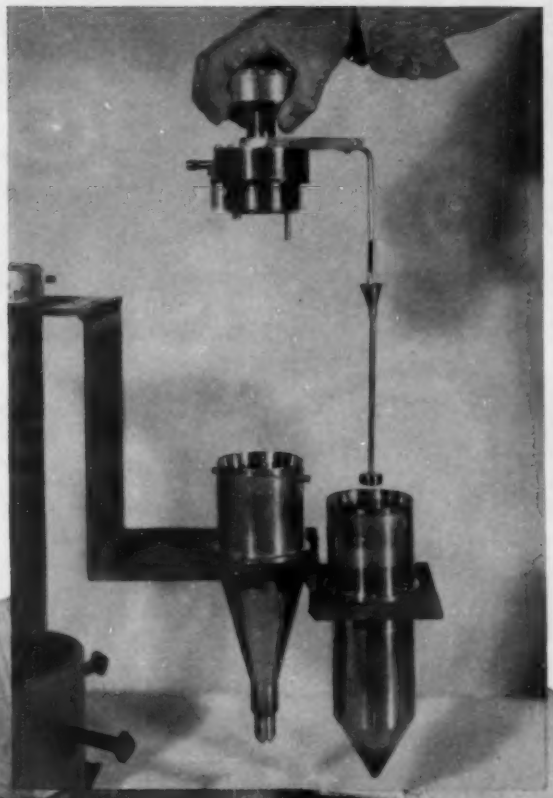
Operator at the control console of the RaLa processing laboratory. The apparatus shown at the right is seen through the periscope.



The apparatus to the left is used for precise alignment of the filtering assembly used in hot cells for RaLa processing. When in actual use it is operated by remote control.

Los Alamos Scientific Laboratory is a non-civil service operation of the University of California for the U. S. Atomic Energy Commission.

This drawing shows the remotely controlled equipment for chemical separation, filtering, drying, pelleting, and jacketing of RaLa sources. Up to 100,000 curies can be handled.

Drawing of Titanium

Digest of "The Drawing of Titanium", by J. S. Kirkpatrick, *The Magazine of Magnesium*, May 1956, p. 2-7.

BECAUSE of titanium's affinity for oxygen, nitrogen and hydrogen, its first applications were limited to forgings, sheet and plate in jet engine parts, in boxes and covers for miscellaneous gear, in areas exposed to elevated temperatures and in pressure vessels. Most of the parts produced are fabricated from commercially pure titanium. However, there is increasing demand for titanium alloy parts which will withstand higher temperatures, in spite of the fact that these are somewhat more difficult to form. For example, commercially pure titanium can be formed at 650 to 800° F., whereas the newer alloys require temperatures of 900 to 1100° F. These increased forming temperatures pose more acute tool material problems.

There are two schools of thought regarding the behavior of titanium and titanium alloys in deformation processes: One group says titanium and its alloys behave like stainless steel; the other claims that titanium behaves like magnesium. Those subscribing to the stainless steel analogy favor staging dies and interstage annealing. Those reasoning that titanium responds more like magnesium favor warm forming.

The benefits resulting from warm forming are said to be (*a*) short exposure to atmospheric contamination due to a rapid heating and cooling cycle, (*b*) single drawing operation, (*c*) minimum scaling which can be removed by blasting or pickling and (*d*) reduction of residual stresses.

Very complicated parts for jet aircraft applications have been warm formed with virtually no scrap losses. Parts have been fabricated on a stretch press die at about 1000° F. from A 110-AT (5% Al, 2.5% Sn). A simple elevated-temperature cupping test has been developed for determining the drawability of commercially pure titanium sheet and is being adapted to testing of alloy sheet. Some experiments have been made with hot rubber-pad forming. Spinning of commercially pure titanium has been done at 600 to 800° F. but attempts to spin alloys have not been successful.

Titanium is formed on hydraulic presses using hydraulic cushions. The presses vary in size from 180 to 750 tons. Various methods are used to heat the dies and the titanium workpiece. These include resistance heating the workpiece, cartridge heaters in dies and gas burner rings. Hand pyrometers and Tempilsticks are adequate for temperature measurement. Warm forming reduces the level of residual stresses produced; however, severely deformed parts are stress-relieved as a precautionary measure. This is done in a vacuum furnace by heating for approximately 1 hr. at 1000 to 1150° F. The formation of beta phase is prevented by this treatment.

A common problem in elevated-temperature deformation processes is that of lubrication. At present, it is not possible to give specific recommendations as to die lubrication for hot forming of titanium.

Scientists ...

Engineers

A message from M. A. Schultz, Project Manager

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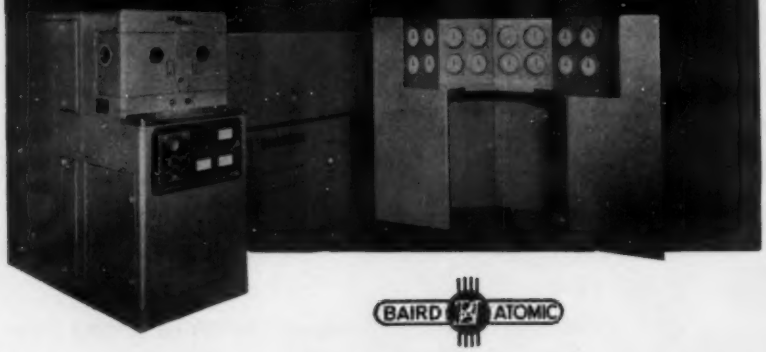

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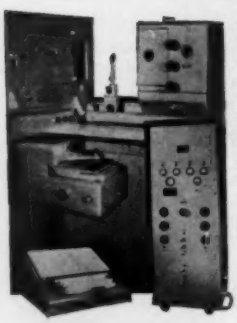

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J. W. SPRETNAK

Effect of Heating Rate on Forgeability

Digest of "A Study of the Effect of Heating Rate by Gas on Metal Flow Characteristics or Plasticity and Die Wear", by Charles A. Turner, Jr. and A. A. Furczyk, Report 1K-7, Committee on Industrial and Commercial Gas Research, American Gas Association, June 1956.

IN MANY PLANTS utilizing fast heating for hot working of metals, benefits resulting from short-cycle heat processing include reduced metal loss by scaling, reduced floor space requirements of the equipment and automation. In addition, an unexpected benefit of considerable importance has been improved forgeability. This improvement has been apparent in different ways, such as less power required on presses, fewer hammer blows to complete a forging, and forging at lower temperatures with no increase in applied power. This condition has been noted in virtually all hot working methods including hammering, pressing, rolling and piercing.

In the early applications of fast heating to forging operations, objec-

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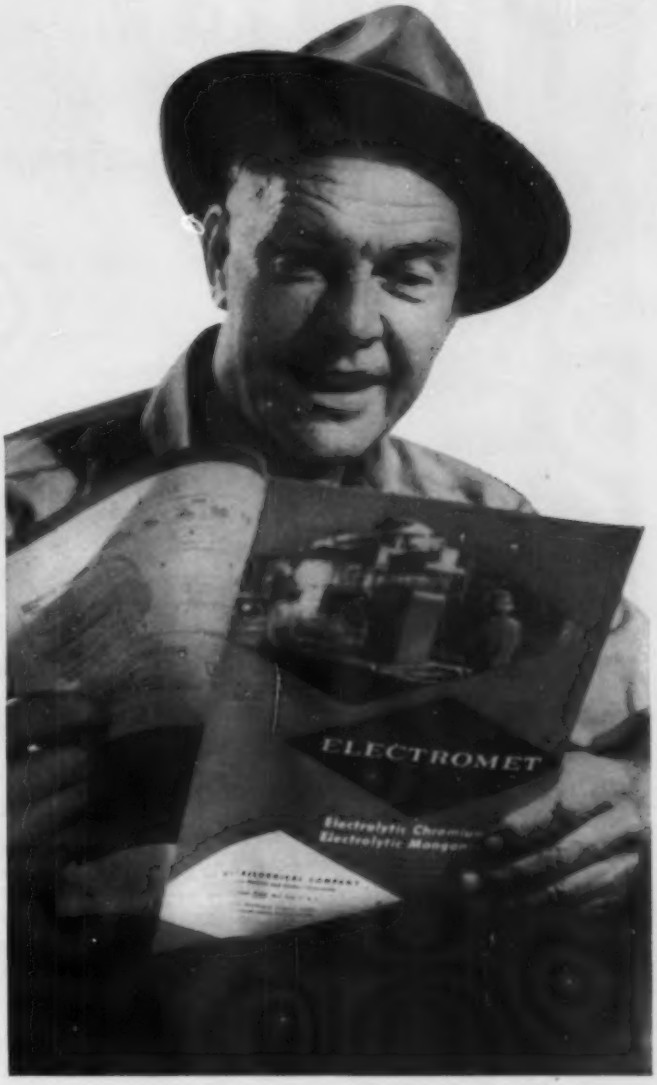

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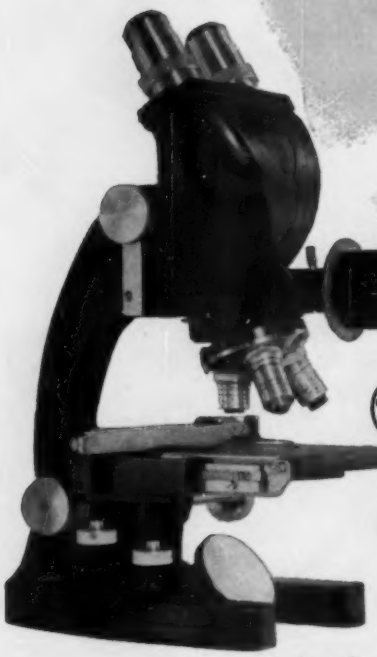

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Forgeability . . .

tions were raised since it was 'contrary to the established practice of heating slowly and soaking at forging temperature. Today, industry is accepting the fast heating method and taking full advantage of its many benefits. In spite of this acceptance, no effort has been made to correlate and evaluate data pertaining to the improved forgeability.

To evaluate the effects of heating rate and soaking time on deformation and structure, a test program was undertaken. Test specimens were heated in a box-type furnace using four radiant burners supplied with premixed gas and air. The furnace atmosphere for all tests was maintained on the reducing side, containing approximately 2% combustibles. In the fast heating method, the furnace temperature was maintained at about 2500° F. and the pieces were moved through the furnace by a column which formed part of the hearth. The heating led to some erratic results since the true temperature of the specimens could not be determined accurately and a study is now being made to eliminate the temperature factor. In the slow heating method, the furnace temperature was the same as the test temperature and all specimens were charged at one time to simulate normal practice. A 2-hr. heating cycle was used. Both carbon and alloy steels were tested.

Three laboratory test methods were employed: a single-blow drop hammer test, a hot-twist test and a hot-penetration test.

The drop hammer test consists of heating a steel specimen to forging temperature and striking it with a drop hammer of predetermined load. The compressed specimen is then measured to obtain reduction in height due to the blow and these data supply the means for comparison of effects of heating rates and soaking times.

The penetration test consists of heating a test specimen to forging temperature and then penetrating it with a round-nosed tapered punch in a hydraulic press.

The hot-twist test consists of twisting a bar of steel to failure at a given temperature while recording the torque and the number of twists to failure. The heating equip-

These intricate, close-tolerance collets weigh less than 10 pounds—are worth nearly $800 each. The manufacturer states: "Our experience with various collet steels proves Crucible collet steel to be superior for flexibility and ability to hold its shape during heat treatment."

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Forgeability . . .

ment used with the hot-twist test machine is a split furnace with the two halves mounted on rollers for opening and closing. Heat is supplied by four radiant burners mounted diagonally in the furnace walls. Fast heating rates are produced with the furnace temperature at 2500° F. The test specimen, with the ends mounted in the twisting machine, is brought to temperature in a predetermined time cycle. The furnace halves are pulled apart when the test temperature is reached and twisting is started. Slow heating is accomplished by stabilizing the furnace at test temperature and allowing the test specimen to heat and soak for 1 hr.

In addition to these laboratory tests, field tests were run on shell forgings which were slugged and pierced under shop conditions. All heating operations were conducted in a box-type furnace with radiant burners and a furnace temperature approximately 200° F. above the desired billet temperature for fast heating and the same as the billet temperature for slow heating. Fast heated specimens were given 17 min. in the furnace while slow heated specimens required 90 min. The most satisfactory billet temperature when using the radiant furnace was 1850° F. instead of the usual 2250° F. This resulted in elimination of the descaling operation and an increase in die life of 50%.

Several conclusions can be drawn from the study:

1. Shorter heating cycles virtually eliminate scale and reduce grain growth.
2. Fast heating permits use of lower temperatures for press work.
3. At equal work temperatures, the forging pressure required is reduced as a result of fast heating.
4. Lower temperatures can virtually eliminate grain growth.

The laboratory tests do not show as much difference in forgeability between fast heating cycles and the conventional slow heating as the field tests. The uses of larger samples and heavier equipment in the field tests leads to more effective results. The mass factor is possibly of much more importance than has been recognized heretofore and more work is required to investigate both this and the other variables which inevitably appear in correlating laboratory and field tests.

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Corrosion by Flue-Gas Condensates

Digest of Part I—"Low-Temperature Corrosion by Flue-Gas Condensates", by R. W. Kear, *Corrosion Technology*, Vol. 3, February 1956, p. 59-64.

THIS PAPER presents an excellent review of corrosion by condensates of the more volatile mineral constituents which are released during the combustion of fuels. It is pointed out that although the character, distribution and chemical combination of mineral constituents differ in various fuels, the presence of sulphur in parent fuel is a common corrosive in all flue bases. Sulphur

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Corrosion . . .

that is not retained in the ash after combustion is oxidized to sulphur dioxide and some sulphur trioxide. These are considered the most corrosive of flue-gas components and can promote serious problems when low surface and gas temperatures allow condensation on combustion appliances. Hydrochloric acid and oxides of nitrogen are the only other flue-gas components which aggravate the corrosion problem.

Since the condensate is a liquid phase, the dew point temperature (highest temperature at which the liquid may exist in equilibrium with the flue gas) is a very important factor and determines whether or not a liquid will exist. Data on the dew point temperatures of gases from a number of industrial appliances are presented.

It is emphasized that the flue-gas corrosion is due mainly to the presence of sulphurous acid and sulphuric acid formed from water vapor and oxides of sulphur. Small amounts of sulphuric acid cause condensation on surfaces at temperatures considerably higher than the water dew point temperature. Sulphur dioxide, oxides of nitrogen, hydrochloric acid and other acid constituents have only small effects on the water dew point temperature.

Most of the sulphur which is released in the combustion of fuels forms sulphur dioxide and a small amount appears as sulphur trioxide. This trioxide is believed to form by the dissociation of sulphates, by the oxidation of sulphur dioxide, or by the catalytic oxidation of sulphur dioxide on the heating surfaces after combustion. The amount of trioxide formed in a combustion appliance is seldom more than about 5% of the dioxide. Water vapor and trioxide react in the cooler flue gas to form sulphuric acid.

The author states that many of the corrosion problems brought about with flue gases would be either avoided or lessened if the sulphur content of the fuel could be diminished. Methods are available for the removal of sulphur from gaseous fuels.

The author differentiates between corrosion by thin acid films condensed from flue gases and corrosion by bulk solutions. It is stated that

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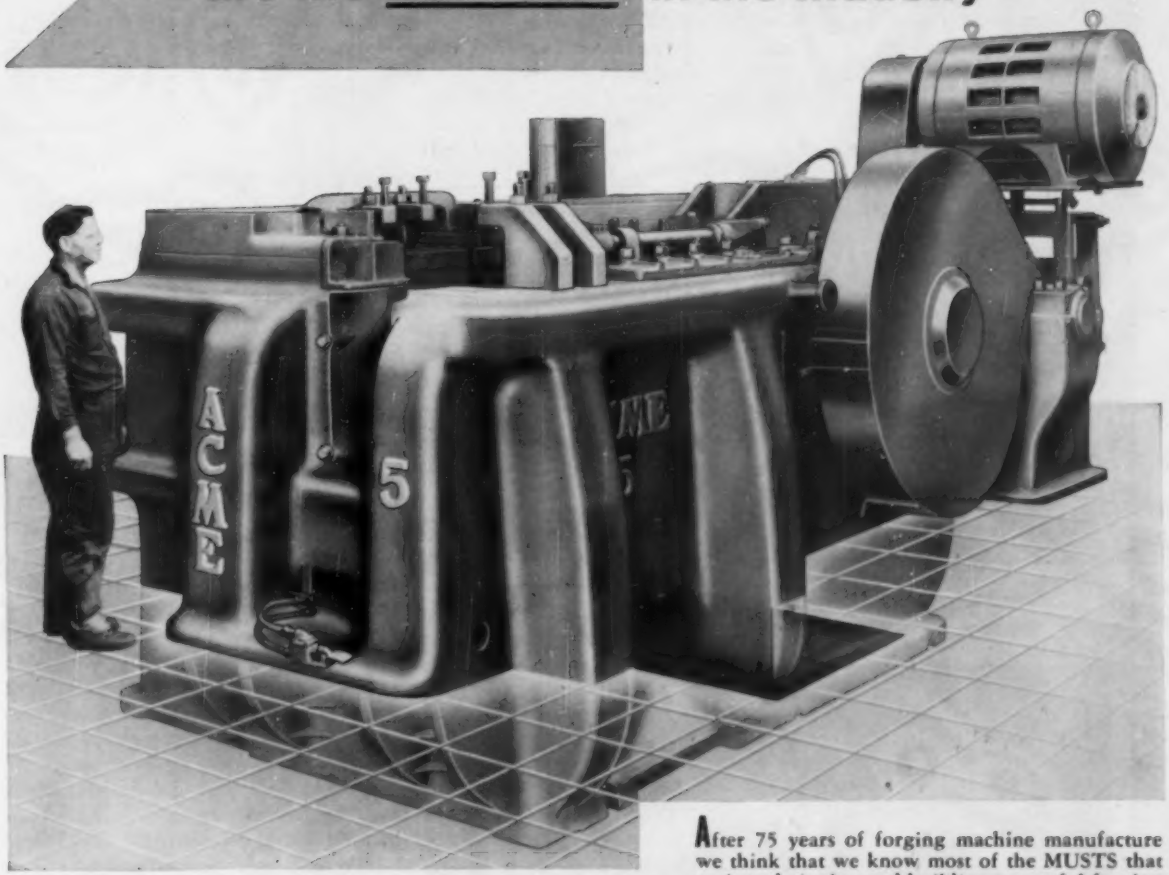

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Corrosion . . .

in the case of thin films the corrosion products are confined in close contact with the metal surface and that this may have a great influence on the resultant corrosion.

Chemical and physical methods of determining the corrosiveness of flue gases are mentioned. The use of the dew point meter in studying the rate of acid condensation (called the rate of build-up) has been found to be a very important tool. The rate of build-up determines the severity of corrosion, while the dew point temperature determines the temperature range over which corrosion occurs.

The concentration of acid which condenses is a function of the surface temperature on which the condensate occurs and the water vapor content. The acid concentration will vary from 69 to 82% sulphuric acid over a surface temperature range of 200 to 275° F. The rate at which the acid deposition and corrosion reach a maximum is about 40 to 80° F. below the acid dew point temperature. Other factors controlling the rate of corrosion include the surface temperature, which in turn determines the acid concentration, and the rate of diffusion of the acid to the metal surface, which is determined by the type of corrosion product formed.

Numerous laboratory studies on the corrosion of several metals and alloys by flue gases are summarized. Effects of acid strength and temperature, sulphur oxides in flue gases, dew point temperatures, fuel characteristics on acid dew point temperature, types of fuel, and air-fuel ratios with fuels of varying sulphur content are included.

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20-Year Corrosion Tests on Aluminum

Digest of "Corrosion Resistance of Aluminum Alloys", *Technical News Bulletin*, National Bureau of Standards, Vol. 40, January 1956, p. 13.

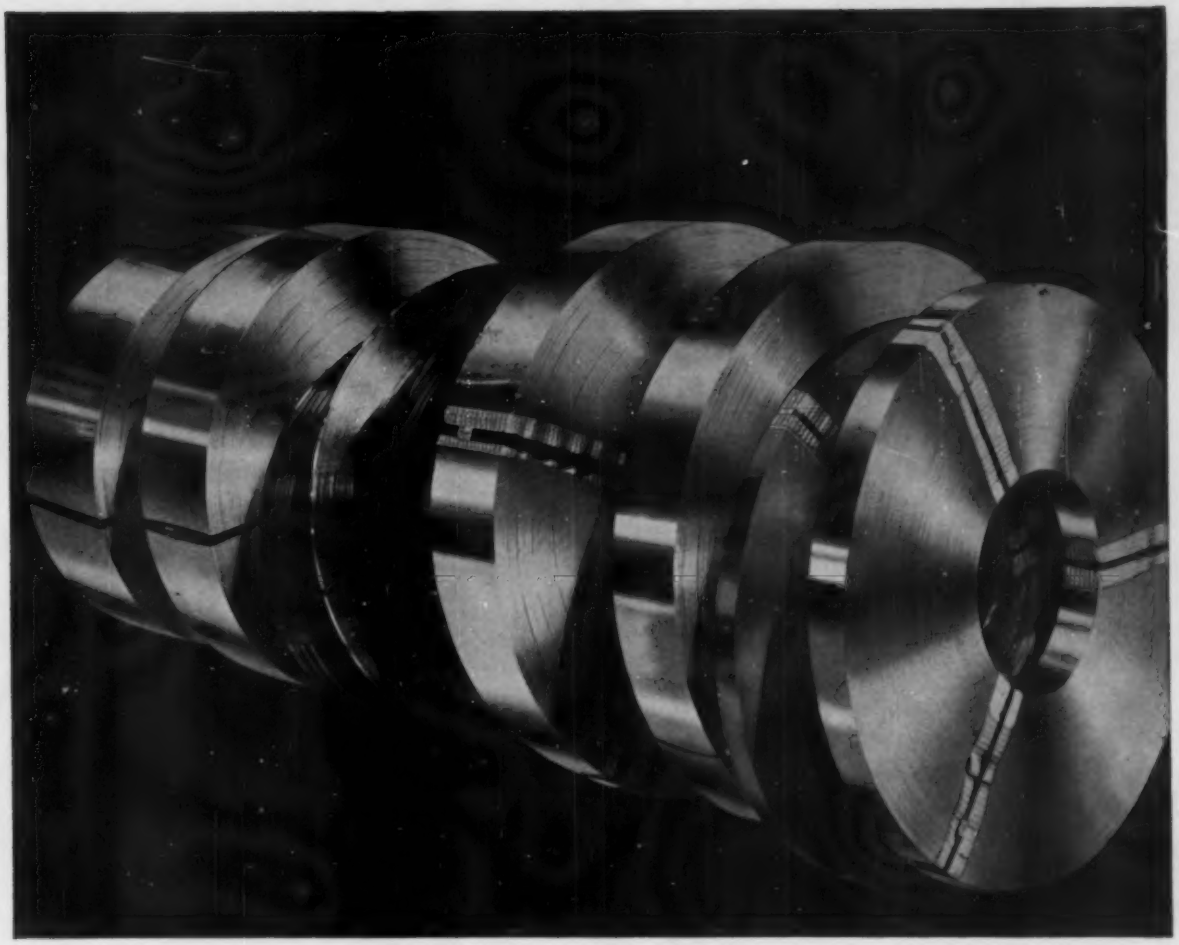
RESULTS of 20 years of exposure to both marine and inland atmospheres on samples of 17 different aluminum alloys have been analyzed by the Bureau of Standards, which conducted the research for the Navy Bureau of Aeronautics. F. M. Reinhart and G. A. Ellinger of the N.B.S. staff supervised the program.

In the early 1930's experimental high-strength aluminum alloys were just beginning to appear for aircraft applications, but little was known of their corrosion properties on sustained exposure. Concurrently there came on the scene a number of new organic paints and inorganic coatings for the light metal alloys. They too needed weather testing.

The alloys studied included those which can be hardened by heat treatment and those not susceptible to heat treatment. Among the latter were aluminum-manganese and aluminum-magnesium types, while alloys amenable to heat treatment included clad and bare aluminum-copper analyses carrying Aluminum Association designations 2017 and 2024. Other alloys contained nickel, cadmium, or copper and cadmium. Aluminum-magnesium-silicon alloys, in which hardening derives from the intermetallic compound MgSi, also were reviewed.

Specimens were strips 0.75 in. wide and 9 in. long. They were set up on racks at a 45° angle in selected locations at Washington, D.C., Norfolk, Va., and the Canal Zone. The latter was representative of tropical marine atmosphere, the other locations of temperate inland and marine environments. All marine specimens were set near the shoreline and were

(Continued on p. 160)



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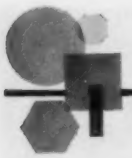

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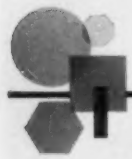

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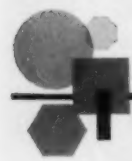

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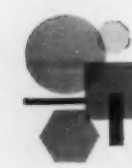

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Corrosion of Al . . .

intermittently wet by salt spray.

Effects of corrosion on each alloy were evaluated by visual and microscopic examination, and also by elongation tests. Samples were removed at intervals from the racks, beginning three months after the start of exposure, and subjected to tensile measurements. Tensile strengths and elongation after exposure were compared with values obtained on control specimens. The latter were obtained by averaging original values and those exhibited by specimens stored in dessicated containers for comparable periods of time. Statistical analysis showed no important differences in these values with respect to time of storage, surface treatment or coating.

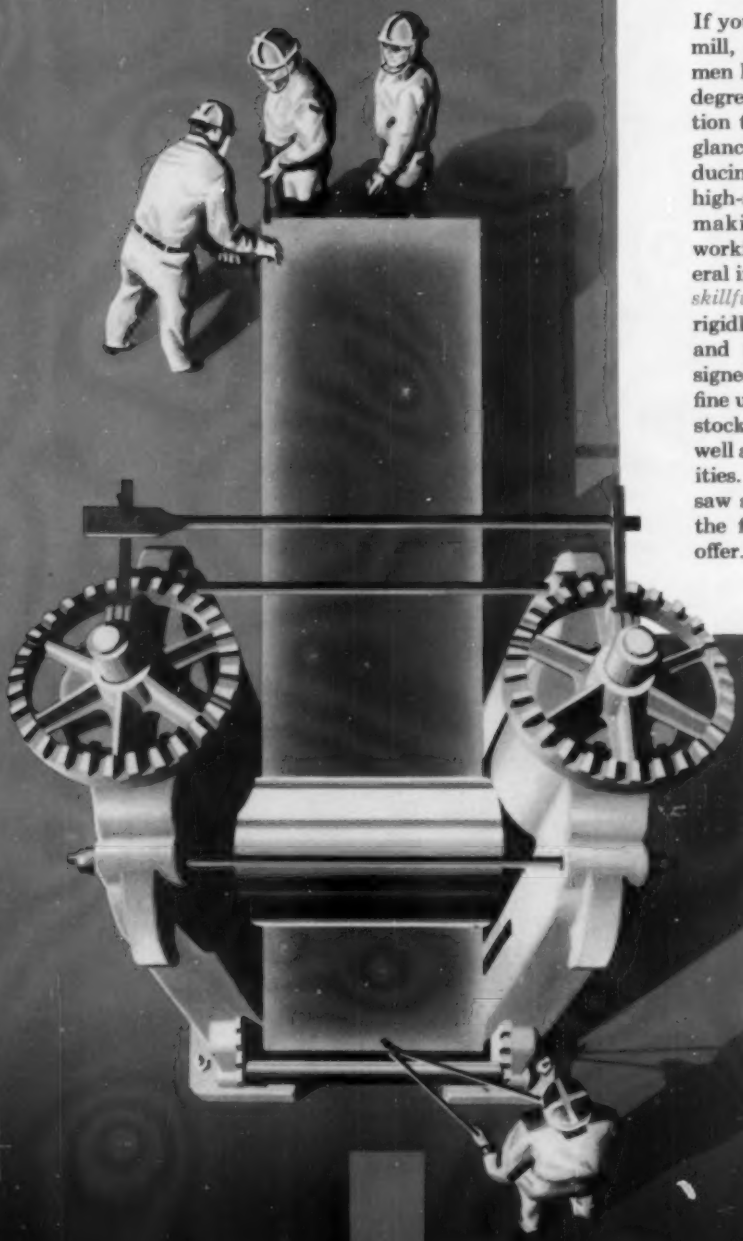
Improperly heat treated aluminum-copper alloys failed by intergranular corrosion and severe exfoliation with no measurable elongation, in contrast to properly heat treated specimens of the same alloys. Those alloys containing both magnesium and silicon showed evidence of intergranular attack.

Spot welded specimens reflected no decrease in breaking strength after 20 years of exposure. When tensile tested, these pieces ultimately either sheared through the welds or the weld nugget pulled out of one piece.

One protective coating tested was a paint consisting of a long-oil ester gum varnish combined with aluminum powder. When applied over various anodically oxidized surfaces of the alloys, protection was increased considerably. In connection with aluminum-copper alloy 2017, it was found that two coats of varnish and aluminum powder applied over a zinc chromate pigmented primer gave complete protection to the bare alloy over the 20-year period.

Since the investigation was begun, compositions of some of the alloys have been altered by producers to improve corrosion resistance, while the commercial use of certain other alloys has been discontinued altogether. Nevertheless, the disclosures of this extended research will prove valuable contributions to the understanding of long-term corrosion of aluminum alloys. ARTHUR H. ALLEN

How Jessop skill makes better saw steel



If you could peer down into the Jessop mill, chances are you'd see groups of men hand-rolling sheets of steel with a degree of skill and careful concentration that might seem excessive at first glance. *Yet it isn't.* These men are producing a very special steel—top quality high-speed sheet which is used in the making of hack-saw blades, woodworking tools, metal-slitting saws, general industrial knives, and the like. But *skillful finish rolling isn't all.* Jessop rigidly controls its melting formulas and pours small ingots specially designed for cross rolling. This insures a fine uniform grain structure so that the stock blanks well, forms well, swages well and has superior edge holding qualities. Remember, when you order your saw steel from Jessop, you are buying the finest that Jessop experience can offer. *And that's mighty fine steel.*

JESSOP

STEEL COMPANY · WASHINGTON, PENNSYLVANIA

OFFICES IN PRINCIPAL CITIES

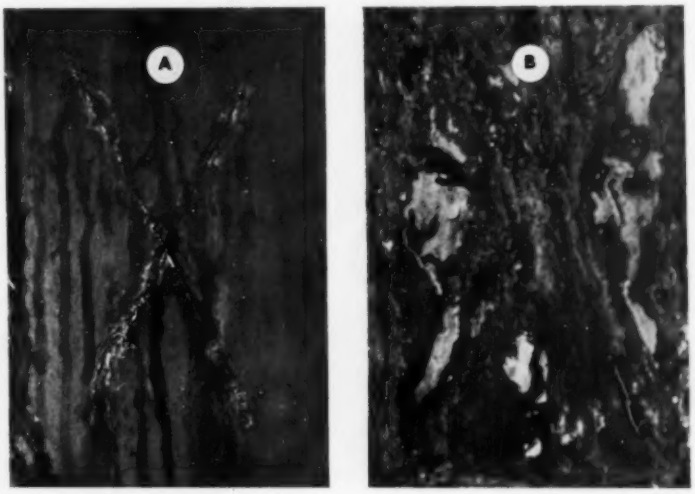
Jessop Steel of Canada Limited, Wallaceburg, Toronto

Jessop Steel International Corp., Chrysler Building, New York, New York

CrysCoat* first, then paint...

to resist rust and peeling

CrysCoat blocks salt spray corrosion. Panel A was Crys-Coated and then painted. Panel B had the identical paint finish, but minus Crys-coat. Both were scratched and salt-spray-tested. Paint on "B" failed at 120 hours. CrysCoat confined rust on "A" to the scratch, with no peeling of paint even after 1200 hours.



A CrysCoated product is *bound* to look better longer. As shown by the panels above, the protective phosphate-coating formed by the CrysCoat Process makes paint stick tight. Becoming part of the metal surface, it stops "creeping corrosion" from undercutting paint... it binds enamels, synthetics and lacquers to the product mechanically and chemically.

There's an Oakite CrysCoat Process to suit your specific production set-up and protection requirements. CrysCoating for zinc or iron phosphating can be done by spray-washer or in tank... with easy control, economy of make-up and other operating advantages. Send for Bulletins F8779 and F9475 which describe CrysCoat Processes in detail. Or take advantage of the CrysCoat Man's ever-ready cooperation.

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SPECIALIZED INDUSTRIAL CLEANING
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MATERIALS - METHODS - SERVICE
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Export Division Cable Address: Oakite

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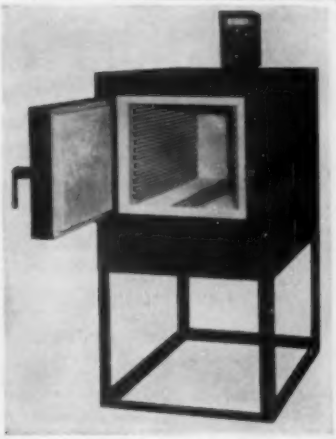
*A complete phosphating process by Oakite

Metal Progress

Bulletin Board...

The Buyers Guide For Metals Engineers



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Furnace Size	2000°	2300°
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Less operator attention needed—Lucifer controls are EXACT. They reach SPECIFIED heat rapidly and retain SPECIFIED temperature without variation. No special experience required when you use a Lucifer Furnace.

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LUCIFER FURNACES, INC.

[illegible], PA.

Phone [illegible] 5-0411

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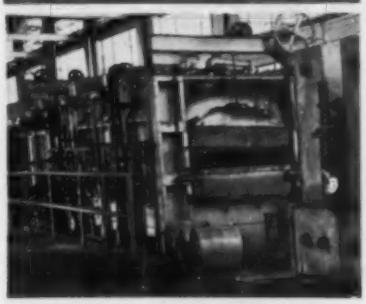
GOOD USED EQUIPMENT AT REAL SAVINGS TO YOU!



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INDUCTOTHERM CORPORATION
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FOR . . . .

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ALUMINUM BRAZING

with continuing graphite electrodes

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MOVES 5 TON LOAD of HEAVY CASTINGS FROM HEATING TO QUENCHING . . .

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Specialists in Processing Carriers Since 1932.

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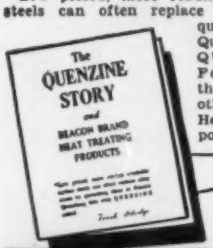

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dyna-trol ELECTRIC FURNACES

MODEL NO.	FIRING CHAMBER (H.W.D.)	PRICE (300° to 2000°)	PRICE (400° to 2300°)
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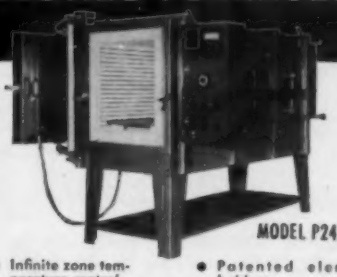
P79	6"x6"x9"	$205.00	$225.00
P918	9"x9"x18"	$480.00	$528.00
P414	14"x14"x14"	$525.00	$603.25
P124	12"x12"x24"	$715.00	$822.25
P818	18"x18"x18"	$775.00	$887.50
P136	18"x18"x36"	$1125.00	$1312.50

Automatic Controls Available on all Models



MODEL P2472-1

MODEL P-79

- Infinite zone temperature control.
- Zone temperature indication by Pyrometer Selector Switch.
- Automatic hold and cut-off instrument available.
- Patented element holders.
- Infinite variety of time-temperature curves obtainable.
- Rugged construction. Highest quality insulation used.

OVER 40 STANDARD MODELS • WRITE FOR LITERATURE

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Grade "B"
FERROUS METAL PROCESSING
Eliminates . . .
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Write for free sample and brochure Specify Grade "B"

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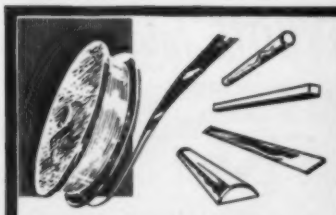

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Beryllium Copper • Bronzes
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THE ULTIMATE LUBRICANT FOR EXTREME HEAT AND PRESSURE APPLICATIONS
RUNNING-IN LUBRICANT
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HEAT REDUCER IN HOT RUNNING
We are so confident of ANTI-SEIZE's performance that we want you to try our sample tube at no cost or obligation. WRITE TO DEPT. D FOR FREE SAMPLE AND LATEST CATALOG.

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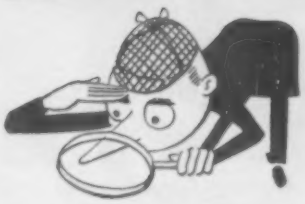
FREE Listing Service for Used Equipment



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LOOKING FOR USED EQUIPMENT?

This new service on used heat treating equipment is completely without obligation to you. To receive the latest availabilities just drop us a line requesting to be placed on our mailing list for a monthly digest. What are your production requirements?

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Swift

SOLUTIONS TO YOUR METAL TREATING PROBLEMS!....

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NOT GRAY
NOT FADED
NOT MOTTLED
BUT RICH, DARK, UNIFORM
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Liquid Carburizer— For a tougher, more durable case!

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METAL CLEANING PICKLING and PLATING COMPOUNDS

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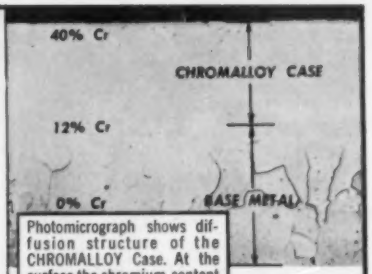
WEAR
CORROSION

CHROMALLIZING diffuses chromium into the surface of iron and steel parts, providing the corrosion resistance of stainless steel and the wear resistance of chromium carbides. CHROMALLOY Case cannot chip, peel or flake.

Chromalloy Corporation is fully equipped for processing large or small quantities of parts. Engineering advisory service available.

FREE! TECHNICAL BULLETINS



Photomicrograph shows diffusion structure of the CHROMALLOY Case. At the surface the chromium content is 35% to 45%.

Chromalloy CORPORATION
451 Tarrytown Road, White Plains, N.Y.
Telephone White Plains 6-0020

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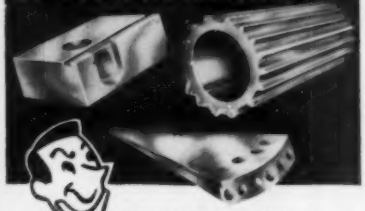

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Bring your idea to specialists in adapting aluminum extrusions to new functional parts applications. G. E. I.'s engineers are ready to consult with you, without obligation, on one part or a million.

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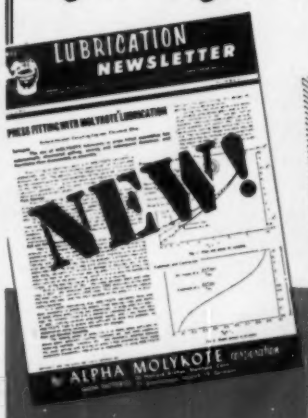

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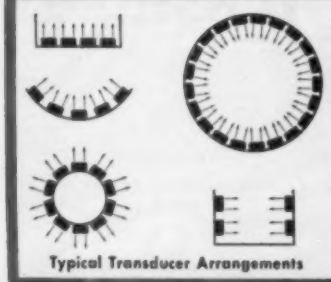
ULTRASONIC CLEANING



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For washing, degreasing, removal of buffing compounds, radioactive contamination, soldering flux, plaster, carbon smut, etc.

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for ALL Industrial Uses

- Degreasing
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ANY SIZE AND SHAPE • ANY DUCTILE METAL

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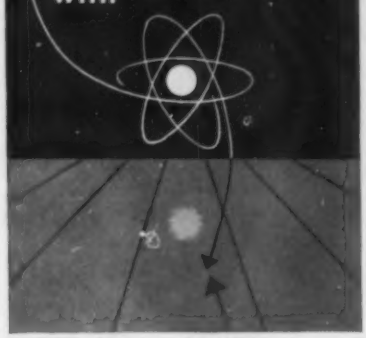
equips you to Electroplate Precious Metals with



SCIENTIFIC PRECISION

Technic, Inc. equips you with controlled apparatus and electroplating solutions to maintain exacting standards and close tolerances. Typical benefits are the spectacular economies Technic effects in handling gold — where often electroplaters lose up to $60,000 or more of every $100,000 worth through outmoded equipment, inefficient methods and solutions.

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TECHNIC BIBLIOGRAPHY

Technic publications, authoritative in our field: "Electroplated Gold"; "Precious Metal Electroplating Data: Gold, Rhodium, Palladium, Platinum, Silver, Nickel"; "Electroplated Platinum"; "Electroplated Palladium"; "Electroplated Rhodium"; "Analysis of Gold & Gold Alloy Solutions".

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THE LARGEST ENTERPRISE OF ITS KIND IN THE WORLD

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NEW pocket size thickness gauge

ELCOMETER

Measures Non-Magnetic Coatings with ± 5% ± .0001" Accuracy

ELCOMETER measures thickness of porcelain enamel, paints, platings, foils, glass, paper, plastics, and other non-magnetic coatings quickly and accurately. Gauges flat or curved surfaces and hard-to-get-at spots easily. Needle locking device assures correct reading every time. Complete with tough leather case containing inner pocket for test strips. Weighs only 6 oz. Completely self-contained. Retail price: $68.00 F. O. B. Cleveland.

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CORROSION RESISTANT

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SINCE 1922

Aluminum and Zinc

HOOVER

THE HOOVER COMPANY
Die Castings Division
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Patent Pending

Accurate test specimens machined from sheet and plate materials .0005 to .500 in., in less than 3 min.

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by N. E. Woldman

This up-to-the-minute book lists over 19,000 alloys by trade name and gives their properties, compositions and typical applications. All important commercial alloys are shown.

1056 pages of valuable information, generous index and tables of manufacturers and the trade names of their products.

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FOR INDUSTRIAL APPLICATIONS

Developed *specifically* for industrial application, Sel-Rex Precious Metals offer many advantages over conventional processes. *One gram* of Sel-Rex BRIGHT GOLD, for example, *does the job of 2 grams* of regular 24 K. gold, because the deposits are more dense and twice as hard. Gives mirror bright finish directly from the bath, regardless of thickness requirements — eliminates costly scratch brushing, buffing and burnishing.

Sel-Rex BRIGHT RHODIUM meets the need of today's precise engineering applications with A. S. C. — Automatic Stress Compensation — a special technique which counteracts the high stress characteristics of conventional precious metal electroplates. Non dusting Sel-Rex Silver SOL-U-SALT is added directly to the plating bath, eliminating time consuming filtering or mixing — a cost cutting advantage exclusive with Sel-Rex.

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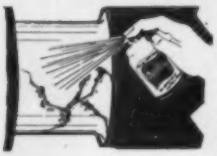

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No solvent required—water removes Dyeline immediately.

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ZIP PATTERN LAYOUT FLUID—Shows up scribed patterns strongly.

ZIP STENCIL INK—Quick drying—excellent on cartons and metals.

ZIP BELT LUBE—Prolongs belt life; promotes safety and speed.

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SHORE SCLEROSCOPE

Pioneer American Standard Since 1907

Available in Model C-2 (illustrated), or Model D dial indicating with equivalent Brinell & Rockwell C Hardness Numbers. May be used freehand or mounted on bench clamp.

OVER 40,000 IN USE

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90-35M Van Wyck Exp., Jamaica 35, N.Y.

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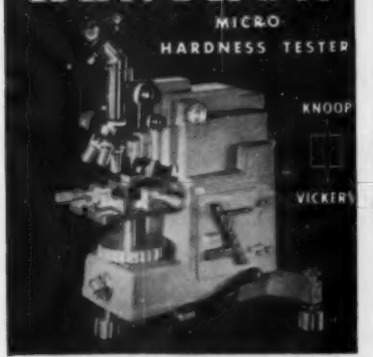

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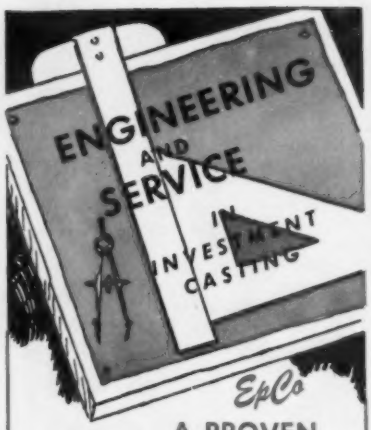

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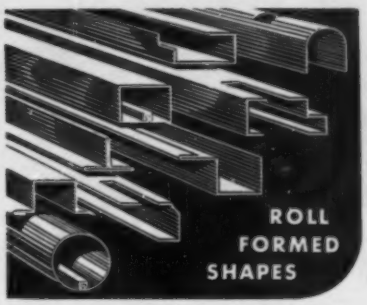

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Heat Treatment of Cast Turbine Blades

Digest of "Effect of Some Selected Heat Treatments on the Operating Life of Cast HS-21 Turbine Blades", by F. J. Clauss, F. B. Garrett and J. W. Weeton, *N.A.C.A. Technical Note* 3512, July 1955, 39 p.

OPERATING LIFE of cast turbine blades can be substantially improved by proper heat treatment. Past laboratory tests have demonstrated the benefits of increasing the high-temperature creep and rupture strength of cast tensile specimens.

With this point in mind, additional studies were conducted for small turbosupercharger blades made of cast Haynes Stellite No. 21 and for wrought bar stock of the same alloy. This report shows the effects of selected heat treatments on service life and mechanical properties at high temperatures. Another investigation was made to determine whether the data obtained for small blades could be successfully applied to large cast turbojet blades of the same material.

Two sources, A and B, were used to obtain turbojet blades of cast Haynes Stellite 21 containing 0.20 to 0.35% C, 1.0% max. Mn, 2.0% max. Fe, 25 to 29% Cr, 5 to 6% Mo, 1.75 to 3.75% Ni and the remainder cobalt. Seventeen of the 20 blades of source A received various heat treatments and the remainder were left in the as-cast condition. One blade of B was retained while four others were heat treated. The heat treatments were divided into an aging process and a solution treating and aging process. The aging process was conducted at 1200 to 1900° F. for 2 to 72 hr. The solution treatment was carried out at 2000 to 2250° F. for ½ to 24 hr. The untreated cast blades were retained as a standard of comparison in micrographs of the as-cast condition.

The blades were tested by installation in a J33-9 turbojet engine operated for a 20-min. cycle under conditions similar to actual service. Testing was conducted for 15 min. at full-rated power and 5 min. at idle acceleration and deceleration. The cycle was repeated for 8 hr. daily until the blade fractured. The zone of fracture in the blade was about 2 in. above the base. In this region the temperature at full rated power

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Turbine Blades . . .

was 1500° F. and the stress was 21,000 psi.

After each failure the blades were examined for surface corrosion, fracture path and microstructural changes resulting from engine operation. The results of these tests are summarized by the authors' conclusions:

1. As-cast blades from source B performed best. Blades from source A had best performance after aging at 1500° F. for 48 hr.

2. The heat treatment that gave best operating life of small turbosupercharger blades decreased the performance of turbine blades of A and B.

3. The effects of heat treatment are dependent upon the initial as-cast microstructure.

4. The best microstructure for heat treatment is a uniform structure with finely distributed carbides and a minimum of interdendritic segregation.

5. Cooling rates and other casting variables must be closely controlled to develop the optimum microstructure so maximum benefits may be derived from the heat treatment.

B. Trock

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A New Pipe Welding Technique

Digest of "Developments in Stainless Steel Welding in the Nuclear Program", by E. B. LaVelle, L. H. Rasmussen and E. M. Kuchera, *A.E.C. Monograph TID-8013*, August 1956, 19 p.

At the Hanford Atomic Energy Commission plant in the State of Washington a large amount of 18-8 austenitic stainless steel, chiefly pipe, is welded with extreme care to avoid defects. A special technique, claimed to be new, is described by the authors. With this method it is easy to make a sound weld having a uniformly smooth inner surface, whereas with previous methods either great skill was required to make smooth crack-free first-pass welds, or accurate machining and assembly were required before welding.

An argon atmosphere is used with a nonconsumable tungsten electrode and filler rod. The 37½° beveled joint is first tack welded, maintaining a gap slightly smaller than the filler-rod diameter. Intimate contact is maintained between filler rod and joint kerfs. The arc is kept as short as possible and is moved along the joint as the filler rod melts.

The parts to be welded must first be freed from oxide and grease within ¼ in. of the joint edges. The atmosphere both above and below the joint must be thoroughly purged, preferably with argon, before starting to weld. (Helium will not provide as smooth an inner weld surface). The electrode, made of thoriated tungsten, should be kept clean and sharply pointed. The arc must always be started on a flat piece of copper fastened to the work close to the joint. The filler rod must be clean, and its composition should be such as will produce ferrite in the finished weld so as to insure freedom from cracks. For welding a 3-in.

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Inserting fluxed spindle and EASY-FLO silver alloy ring into lower half of spool. Assembly is completed when upper half of spool is pressed onto spindle. Press fit is necessary to maintain proper joint clearance between brass spool and steel spindle at brazing temperature.

Sliding burner assembly into heating position. Weight of upper platen assures accurate joint fit when ring of EASY-FLO alloy melts. Fuel is mixture of city gas and oxygen. Operator brazes 20 to 30 spools per hour.

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For example, when nylon line first appeared, Ocean City Manufacturing Company, the country's largest manufacturer of fishing reels, realized that the design of the reel spool would have to be changed. This because, with a big one on the line, the tremendous compressive forces of tightly wound elastic nylon often caused the spool flanges to spread so that the spool bound against the reel housing. Silver brazing with Handy & Harman EASY-FLO 45 silver brazing alloy and HANDY FLUX permanently and simply solved this serious problem.

Originally the spools were assembled from two fully machined brass forging halves with the hollow hub of each half fitted over a solid steel spindle with the drive clutch at one end. Each half was secured with ⅛" stainless steel pins driven through the spool hub into the internal spindle.

The same spool components are still used except that now semi-machined brass spool halves are silver brazed directly to the steel spindle with a preplaced ring of EASY-FLO 45 alloy. The shear strength of the brazed joint now exceeds 40,000 psi and because of the greater area of adherence to the spindle (as compared to two stake points previously used) spool hub creep toward the spindle ends is eliminated. The alloy cost is only 1.3 cents. The assembled spool is now finish-machined as a unit. The machining time once required for drilling and aligning has been eliminated. And when time is reduced and a product is improved, costs are reduced and sales are improved.

These same benefits could easily apply to the production of your product. The simple fact is that silver brazing with Handy & Harman brazing alloys has paid off handsomely for those who use it. The only way to find out if and how your product or methods fit the picture is to ask us —we'll be delighted to work with you all the way.

TO HAVE AND TO HOLD

BULLETIN 20 tells you why high strength, speed and economy are inherent in EASY-FLO silver brazing. Also gives Handy information about joint design and fast brazing methods. We'll be pleased to send you a copy.

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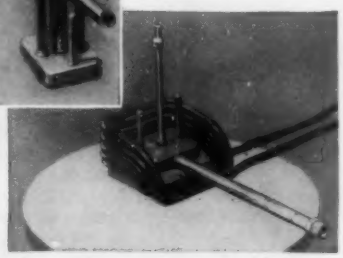

The simultaneous soldering of a group of components within one load coil is an ideal application for induction heating. The assemblies consist of mounting studs and tubes inserted into a machined part together with preformed solder rings. The heating is done so rapidly that there is practically no scaling or discoloration.

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Pipe Welding . . .

pipe, using a 3/32-in. diameter filler rod, a single-phase d-c. current of about 90 amp. is satisfactory.

The joint edges should be beveled 37½°, maintaining either a feather edge or an edge not over 1/64 in. wide. Spacing should be a little less than the filler-rod diameter, but complete accuracy is not essential in either spacing or alignment.

In welding two pipes together, the ends must be rigidly supported before tack welding. For pipe of 2 to 4 in. diameter, the tack welds should be about 90° apart and ⅜ to ½ in. long. The filler rod must be held tangent to the circumference with its end pressed into the beveled joint with enough force to cause it to bond slightly. It may be straight or formed to fit around the pipe in the weld groove. The arc is moved steadily along as the rod melts, with the arm always directed toward the pipe axis. Arc length is maintained by resting part of the hand against the pipe. Loss of the protective argon atmosphere inside the pipe is prevented by applying masking tape to the unwelded joint gap.

The filler rod can be lowered into the weld puddle, but even progress of the arc with little movement of the rod gives a smoother weld. To interrupt the welding sequence, the arc is simply withdrawn slowly from the filler rod. Later it can be restarted on the rod. If the outer surface is only very slightly concave, the inner surface will be flat. Operators can be readily trained to produce smooth inner surfaces. The outer surface should be brushed while hot to remove any oxide before further weld passes, and the wire in the brush must be stainless steel.

In welding subsequent passes, special care must be taken to apply heat evenly so as to avoid melting through the first pass. For pipe of 2 to 4 in. diameter, 3/32-in. filler rod is suitable. The electrode should weave from side to side of the joint as the weld progresses, inserting the filler rod into the weld puddle as the arc approaches the side and withdrawing it as the arc leaves the side. This prevents too deep a molten puddle in the middle. A wash pass, without filler metal, may be used to smooth the final outside surface.

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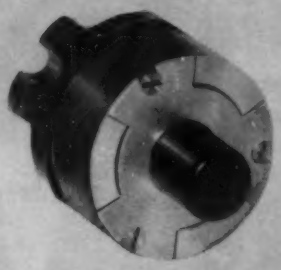
HOW CHACE THERMOSTATIC BIMETAL ACTUATES THE

RBM

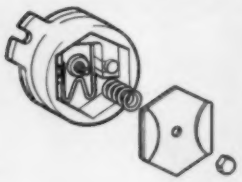
MOTOR PROTECTOR

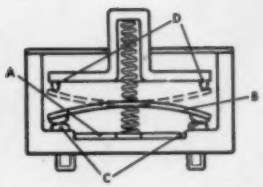
AUTOMATIC RESET—#91300, #91400



MANUAL RESET—#92300, #91400

A PRODUCT OF RBM DIVISION OF ESSEX WIRE CORP. LOGANSPORT, IND.





After years of development by RBM Division of Essex Wire Corp., and now in volume production, this bimetal motor over-load protector provides overload protection for split phase or capacitor motors such as are used in many household appliances. It may also be used with 110/220 volt motors of heavier capacity. The disc-type element is sensitive so as to give instant response to locked rotor current, yet carry starting surges and protect against running over-loads. The calibration to trip at 105° (also 120°) allows for ambient compensation for varying temperatures within the motor. The box shape of the terminals prevents soldering spatter and the double break contact provides long contact life. The snap-action disc element is fabricated from Chace Thermostatic Bimetal.

Here's how the manual reset protector works: The heater wire (A) carries a normal load but is heated by locked rotor currents or running overload currents. The heater in turn heats the thermostatic bimetal disc element (B) until at the calibrated temperature it snaps into the reverse shape, opening the contact points (C); when the reset plunger is depressed after correction of the failure, the two buttons (D) contact the bimetal element, forcing it to snap back into its original shape with contacts closed.

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Pipe Welding . . .

for flat welds between plates, but a special fixture is required in order to maintain the protective atmosphere on the underside of the joint. With an adequate protective atmosphere, it is easier to weld plates than pipes.

This technique has been used successfully for carbon steels as well as stainless, and smooth joint surfaces can be confidently predicted.

G. F. COMSTOCK

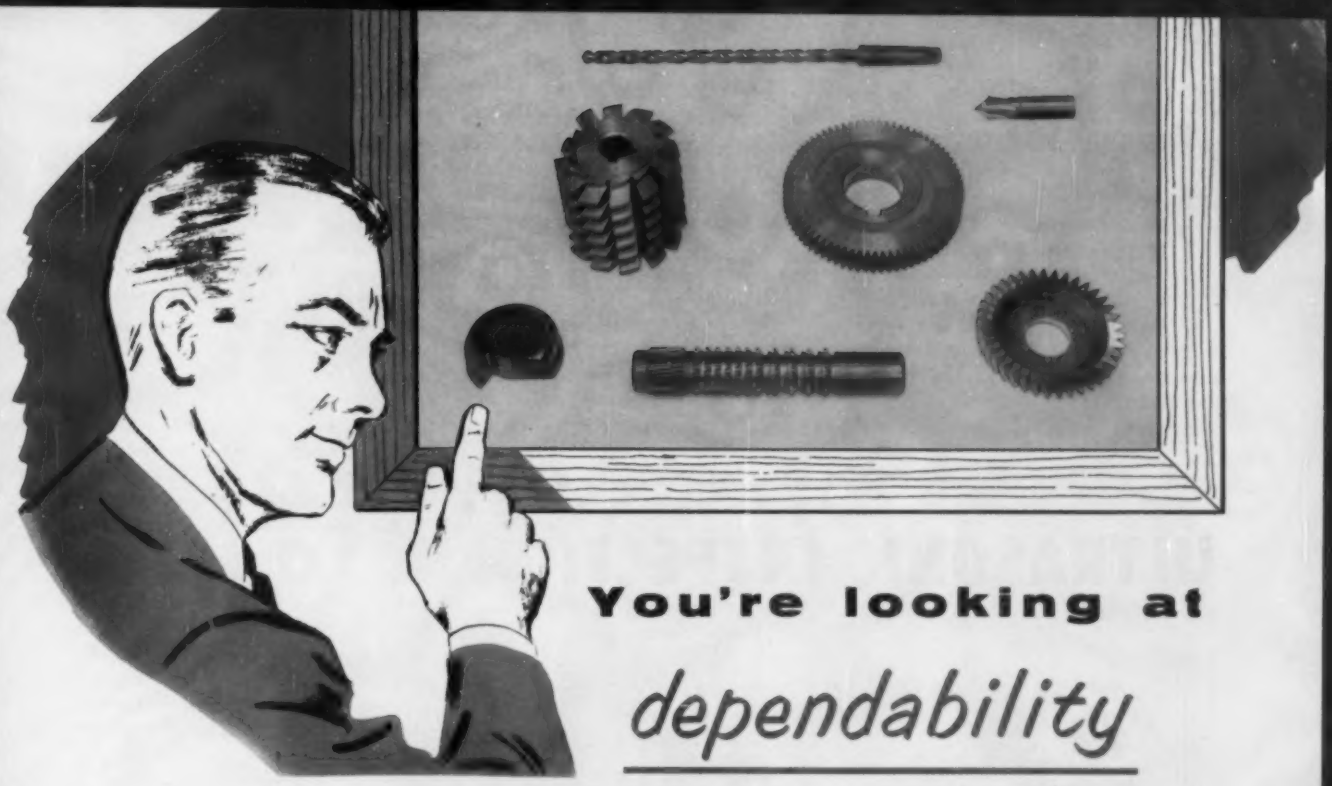
Russian Research on Residual Stresses

Digest of "Role of Residual Stresses in the Fatigue Strength of Shafts with Stationary Fittings", by I. V. Kudryavtsev and N. M. Savvina, *Metallovedenie i Obrabotka Metallov*, No. 5, November 1955, p. 17-23; and "Residual Stresses in Case Hardening by Induction Heating", by G. F. Golovin and D. A. Kotsylo, *Metallovedenie i Obrabotka Metallov*, No. 5, November 1955, p. 28-32.

THESE TWO PAPERS not only contain useful information but also illustrate some fresh approaches to problems involving residual stresses.

Kudryavtsev set himself the problem of showing whether residual stresses are actually the cause of the beneficial effect of surface deformation, such as surface rolling and shot peening, on fatigue strength. An alternative explanation would be that the plastic deformation involved raised the tensile strength of the metal and therefore raised the fatigue strength correspondingly. The method devised to get at this problem was to use plastic deformation by torsion to raise the over-all hardness of a reference specimen the same amount that the surface hardness of a normal specimen was raised by surface rolling.

The two kinds of specimens were first tested in a conventional rotating-beam endurance machine and both were found to have strengths about 20% higher than an unhardened specimen. Next, a sharp stress concentration was produced in the specimens by fitting a stationary collar of the gage length of the specimens. Under this condition the surface rolled specimen had an endurance



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Residual Stresses . . .

limit that was 100% greater than the specimen strengthened throughout its cross-section by torsion. In fact, the latter specimen was no better than one not hardened at all.

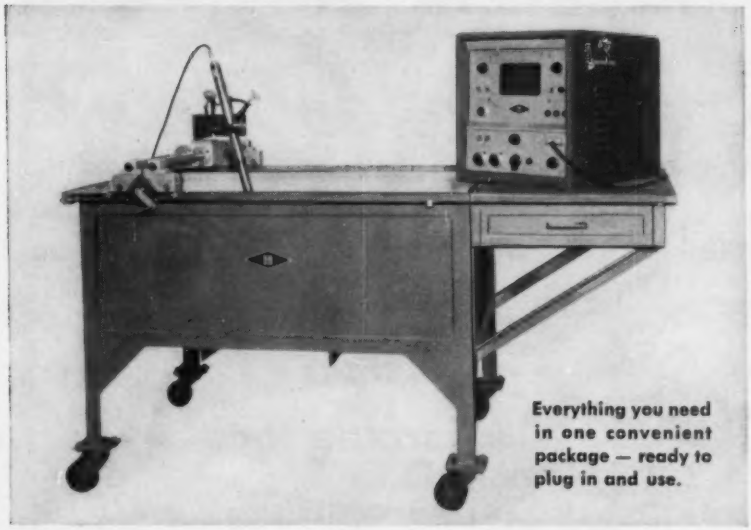
Actual measurements of residual stress gave 78,000 psi. maximum compressive stress in the surface rolled specimen and essentially zero stress in the other. As verification of the importance of residual stresses under fatigue conditions, it was shown that an 87% improvement in fatigue strength was achieved by water quenching a steel specimen from 1100° F., thus producing a maximum residual stress of about 44,000 psi.

The purpose of the second paper was to investigate the character of residual stresses produced when a section of a cylindrical steel bar is induction hardened. A novel variant of the Sachs' "machining-off-layers" technique was employed. Two microhardness indents were made at a convenient separation in the direction in which the stress was to be measured; then a layer of steel was machined off on the far side of each indent. From the change in separation of the indents, the magnitude of the residual stress could then be determined.

In this manner it was found that both the axial and tangential residual stresses in an induction heated, water quenched 0.45% carbon steel reached values in excess of 100,000 psi. in compression. More important from the standpoint of cracking, however, was the fact that *tensile* stresses of 28,000 psi were found at the edges of the hardened zone. Both tensile and compressive residual stresses were reduced by tempering and it was found that temperatures in the range of 400 to 480° F. were the most suitable.

A. G. Guy

ULTRASONIC INSPECTION



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Use of Oriented Steel in Turbine Generators

Digest of "Oriented Steel and Today's Turbine Generators", by G. W. Staats, *Allis-Chalmers Electrical Review*, Vol. 21, 1st Quarter 1956, p. 18-20.

Grain-oriented steels have been widely used to improve the electrical characteristics and reduce the size and weight of transformers. Recently the use of this steel has been extended to the construction of stators of large turbine generators, giving reduced core losses and reduced field current for a given generator load.

The principle involves the orientation of the axes of easiest magnetization parallel to the direction of rolling. Thus a high permeability in the direction of rolling and low core losses result. These desirable properties may be obtained in silicon iron through a controlled process of cold reduction at the mill.

Tests show that the core loss at high flux densities is very dependent on the angle between the flux and rolling direction. The core loss is substantially less at angles under 30° to the direction of rolling than at greater angles. For stress-annealed 29-gage (0.014-in.) oriented steel,

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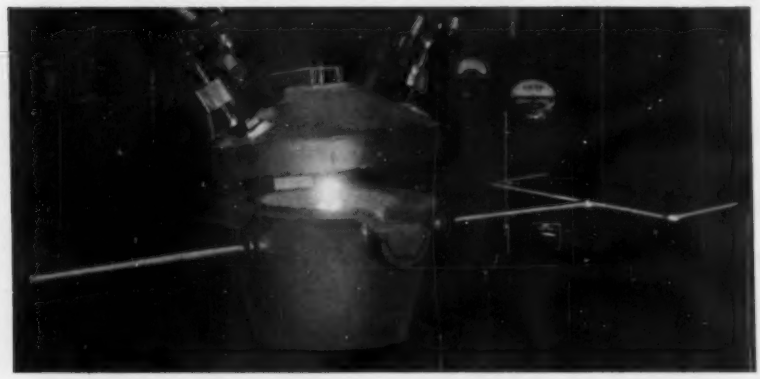

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Oriented Steel . . .

the core loss at 60 cycles at a flux density of 15,000 gausses (96,750 lines per sq.in.) at 0 to 90° to the direction of rolling is approximately 0.6 and 2.1 watts per pound, respectively. The excitation requirements for oriented steel are also substantially lower as the angle of induction to the direction of rolling is decreased. At 15,000 gausses for the same material as above, the exciting r.m.s. volt-amperes per pound for flux at 0 to 90° to the rolling direction is approximately 0.8 and 30, respectively.

The physical and mechanical properties of grain oriented steel at room temperature were studied. An interesting variation was found in the modulus of elasticity with orientation of the test piece to the rolling direction. The average modulus of elasticity in the rolling direction was 19,000,000 psi. and at right angles to the rolling direction 27,700,000 psi. This variation, while it may be significant for certain applications, is not a limitation on mechanical design of a generator core, since the angle between both circumferential and radial directions and the direction of rolling change from point to point in a given lamination, and also because the laminations are staggered as the core is assembled.

To obtain the full advantage of the superior magnetic properties of oriented grain, the laminations that have been punched or sheared from fully processed material should be annealed at 1475° F. for 1 hr. (a stress-relief anneal). This treatment is desirable because the material is more strain sensitive than other electrical steels having essentially nondirectional magnetic properties. Annealing in an inert atmosphere is recommended.

In service stators made of oriented steel have been compared with those manufactured from other types of steel. A comparison of two such 93,750-kva. generators in the same power station, showed that the use of oriented steel decreased the core loss 36% at rated voltage. Since core loss is a fixed loss, efficiency is improved at all loads. Neither machine noise nor vibration has been increased perceptibly by the use of oriented steel.

W. A. MORGAN

some people have queer notions about

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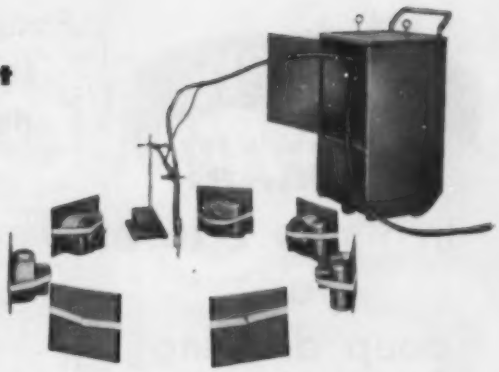

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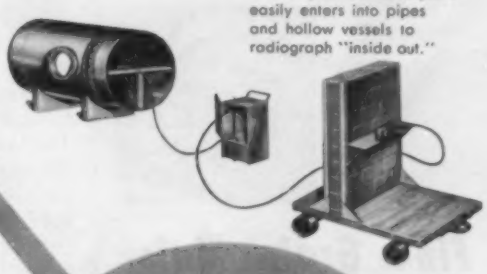

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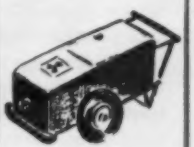

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Precipitation Hardening for Creep at High Temperature

Digest of "The Structural Hardening in the Low Alloyed Steels for Creep at High Temperature", by L. Habraken and A. de la Motte; Joint Metallurgical Societies Technical Session in Liège, Belgium, No. 57, June 13, 1955, 14 p.

A HEAT TREATMENT which produces a fine precipitation in low-alloy steels improves their resistance to creep at high temperatures. The precipitation may be produced by tempering before the creep test or at the beginning of the test. In low-alloy steels the precipitates that have been found to strengthen the structure are alloy carbides, and to be effective they must be capable of being formed in normalized steel. The best heat treatment depends on the nature and previous condition of the steel and must be determined for each composition.

A large amount of data was obtained by the authors of this paper from creep studies of low-carbon Cr-Mo-V-W steels. The precipitates causing structural hardening in these steels were identified by optical and electron metallography and by X-ray examination of the steel matrix and precipitates extracted by anodic solution of the metal.

In a steel containing 2.25% chromium and 1% molybdenum cooled at various rates from 1760° F. a hardening precipitate of a special carbide called "X-phase" was found in the ferrite after tempering only when the quench was slow enough to produce pearlite. With bainitic transformation, the presence of martensite gave an acicular structure with rapid cooling, or with slower cooling such as normalizing a Widmanstätten structure of ferrite and austenite was formed, with part of the austenite sometimes decomposed to ferrite and carbides. These structures were illustrated and the presence of austenite was confirmed by X-ray examination.

In the 1% Cr, 0.5% Mo steels containing 0.4% V or 0.4% V plus 0.5% W, the pearlitic and bainitic transformations were not separated, and occurred more rapidly. Normalized specimens contained much ferrite, and precipitated carbides, including

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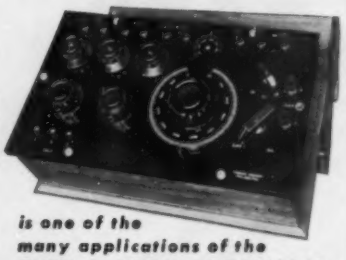

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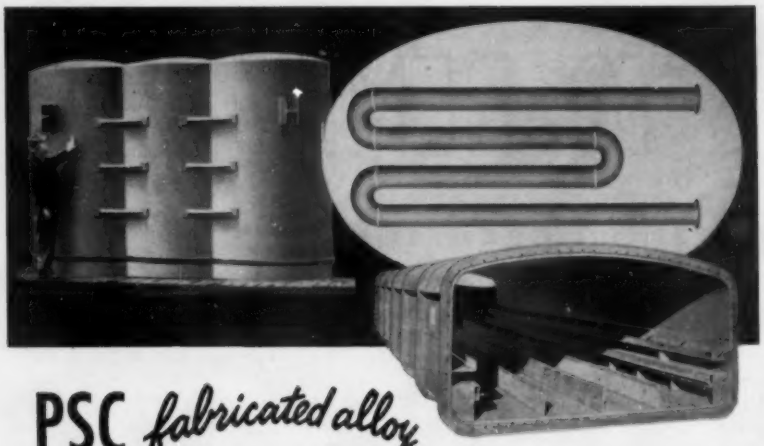

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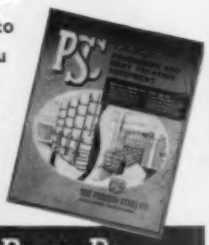

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Creep . . .

V_4C_3, were found in the ferrite. These steels were not so sensitive to air cooling as the plain Cr-Mo steel (probably because of lower alloy content).

The changes in hardness in these three steels after normalizing and tempering at various temperatures and times up to 10 hr. were presented graphically. The hardness as normalized was appreciably greater in the 2.25% Cr, 1% Mo steel than in the others and its greatest hardening occurred on tempering 1 hr. at 1020 to 1110° F. No data are given for the other steels tempered. Tempering all three normalized steels at 1355° F. for an hour brought them all to about the same hardness. X-ray tests on carbide residues from the tempered steels indicated that in the Cr-Mo steel the precipitate causing the temper hardening was the "X-phase". It was established that the hardness peak at 1020° F. was due to austenite decomposition. Temper hardening in the other steels was ascribed to V_4C_3.

Creep tests in this investigation were made at 1020° F. on the 2.25% Cr, 1% Mo steel normalized 2 hr. at 1760° F. and tempered 4 hr. at 1250° F. With this tempering the hardness was below the maximum, but the precipitate of X-phase was sufficiently fine and well dispersed to be effective. During the creep tests the X-phase coarsened after 1000 hr. and $M_{23}C_6$ appeared at grain boundaries.

Creep tests were made at 1070 and 1110° F. on the steel containing 1% Cr, 0.5% Mo, and 0.4% V, normalized 2 hr. at 1785° F. and tempered 5 hr. at 1330° F. Tests also were made on steel containing 1% Cr, 0.5% Mo, 0.5% W, and 0.4% V. This steel was tempered at 1310° F. When tempered 8 hr. the creep strength of the steels decreased. The principal change in the structure was coalescence of the V_4C_3 precipitate.

In the Cr-Mo steel, ferrite that was formed with pearlite on normalizing precipitated a carbide on tempering 30 hr. at 1350° F. The precipitate was identified as M_6C plus $M_{23}C_6$. Ferrite that was formed with bainite on normalizing precipitated the X-phase at 1020° F., and precipitated M_6C plus $M_{23}C_6$ at 1290° F. The residual austenite

Tool Steel Topics

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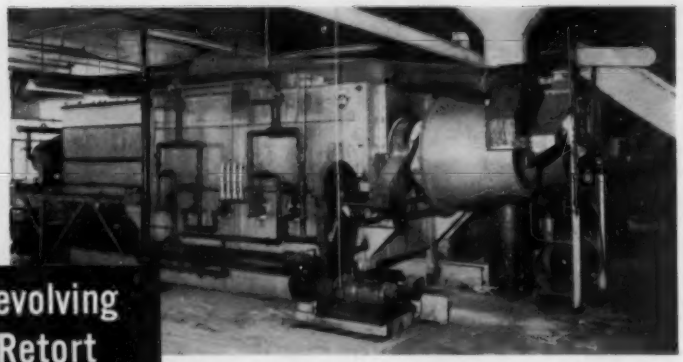
Attempting to double everything may be a wise policy in the investment field. But it can cause trouble when applied to the selection of tool steels. For example, when a successful production line is to be duplicated in larger size, the same grade of steel should not be used for each part without further consideration.

The main difficulty which arises is that the steel for a given part may not have sufficient hardenability when the part is to be made in a larger size. The reason is that tools which have been only partially hardened through will not be as strong as the deeper hardened or through-hardened tools of the original model. Secondly, the use of low-hardenability steels may be troublesome because the larger tools may be under-tempered in attempting to develop the desired degree of surface hardness. You may find that tools which are improperly tempered sometimes crack in treatment, grinding, or in service. Steel for each tool must therefore be selected with reference to the size in which the tool is to be produced.



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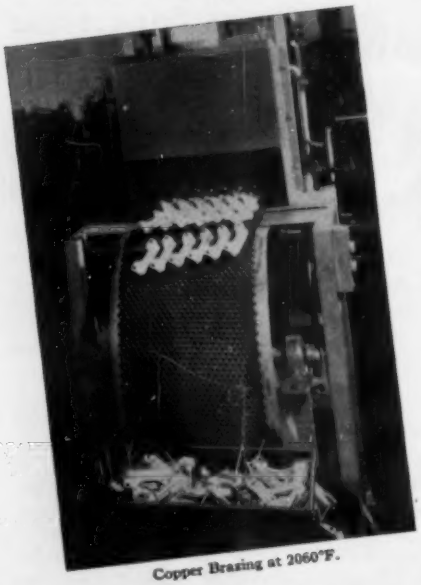

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WRITE FOR ILLUSTRATED CATALOG M 55

Creep . . .

decomposed to ferrite plus M_3C above 750° F. and to ferrite plus $M_{23}C_6$ above 930° F.

In the other steels the only precipitates considered sufficiently important to discuss were those found in the propearlitic ferrite. In the Cr-Mo-V steel, a precipitate of V_4C_3 appeared after a few hours at 1200° F., and after 1000 hr. at 1110° F. an unidentified other carbide was also found with V_4C_3. In the Cr-Mo-V-W steel the precipitates found were V_4C_3 after tempering, V_4C_3 plus X-phase plus an unknown carbide after 1000 hr. at 1070° F., and V_4C_3 plus M_4Mo_2C after 3000 hr. at 1110° F.

The decomposition of X-phase to M_4Mo_2C at 1110° F. accounts for the lower creep strength of the Cr-Mo steel at 1110° F., although its creep strength was considered satisfactory at 1020° F. where the X-phase was stable and coalesced very slowly. Similarly, the satisfactory creep strength due to V_4C_3 in the Cr-Mo-V steel was affected by the appearance of the unidentified carbide. In the Cr-Mo-V-W steel the creep strength was reduced due to changes in the precipitate. Thus in all these steels, transformations in the originally fine and well-dispersed carbide precipitates affected creep properties.

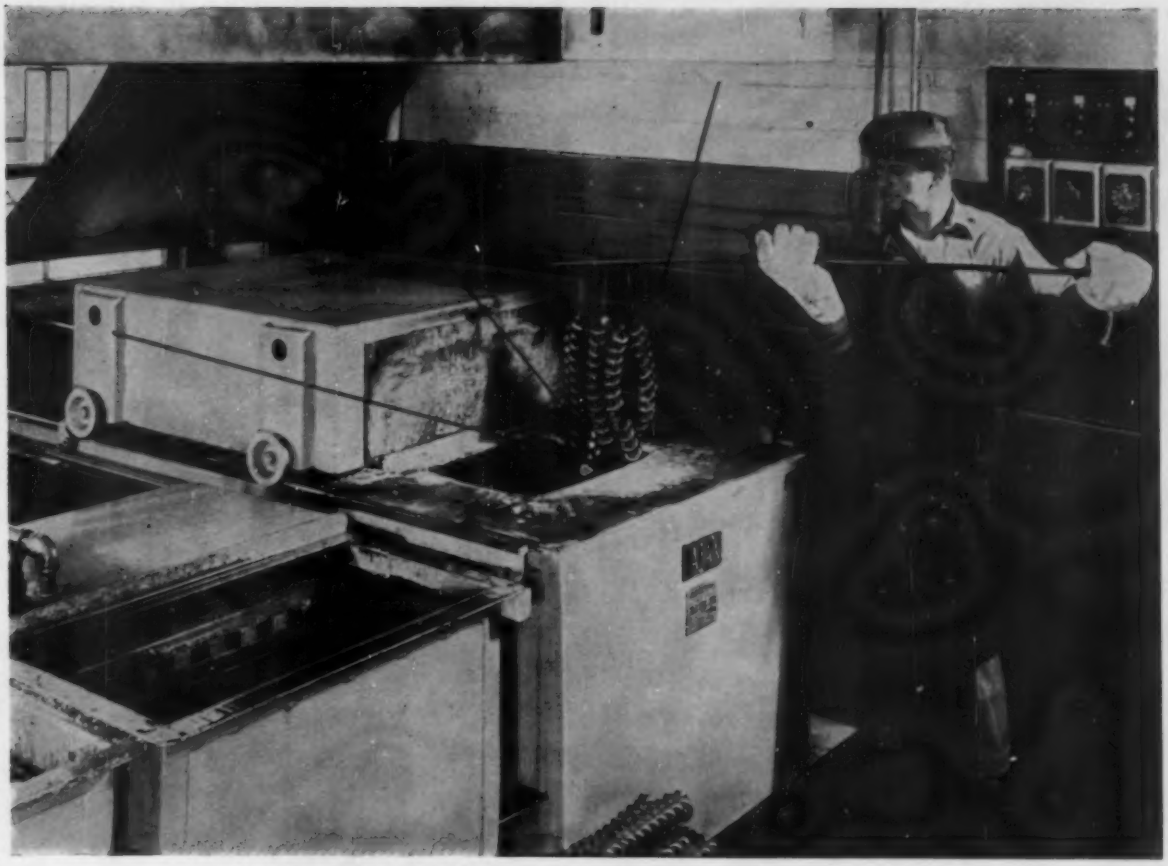
GEO. F. COMSTOCK

Uranium's Fire Properties

Digest of "The Fire Properties of Metallic Uranium", by R. B. Smith, Atomic Energy Commission *Monograph TID-8011*, April 1956, 11 p.

IN GENERAL, the fire properties of metallic uranium are similar to but more pronounced than those of magnesium of similar form. Under suitable conditions, uranium is capable of self-sustaining combustion in air, nitrogen, oxygen and carbon dioxide. The reaction at high temperatures between steam and uranium is much more vigorous than between oxygen and uranium.

Self-sustaining combustion of uranium is accompanied by emission of very intense but localized heat and light. The metal burns without



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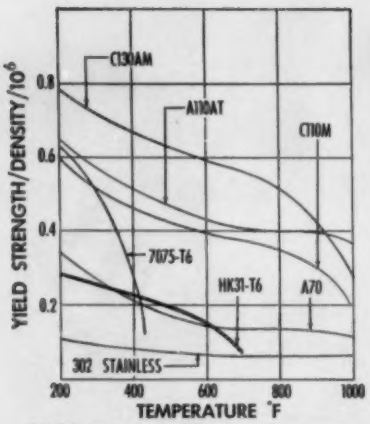

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Uranium . . .

flame. The heat has often been sufficient to burn holes through supporting thin sections of steel. Once initiated, the rate of metal combustion is little affected by the porous oxides that are created. The rate of combustion may range from explosively violent to very slow quiescent burning. Burning uranium is capable of violently reacting with all commonly used fire extinguishants.

Massive uranium is normally incapable of self-sustaining combustion in air without the continued application of heat from external sources. The occurrence of fires during rolling, extrusion, forging or storage, is exceedingly rare. The frequency of fires that may be expected while metallic uranium is being sawed or while lathe or milling operations are being performed will vary with the type and rate of coolant application. If no coolant is used, the sawdust or chips will often spontaneously ignite in air at the time of their creation. If water — or water-soluble vegetable oil — is applied as a coolant, sporadic minor fires may be expected in the metal chips or sawdust at the time of their creation. However, if mineral oil coolants are liberally applied during machining operations, few if any spontaneous fires may be expected to occur. The hazards of spontaneous ignition may be minimized by storage of chips under mineral oil. Controlled incineration or digestion by chemical means affords the safest method for averting fire hazards from uranium turnings.

Finely divided uranium metal powders are usually highly pyrophoric. Grinder sludge, for example, may spontaneously ignite while immersed in water for periods of a day or more. If the metal powder is dispersed in air, spontaneous explosions may be expected.

Unusually high pyrophoricity may be displayed in uranium either as surface phenomenon or as a uniform characteristic of all metal in the specimen. Several incidents will serve to illustrate some of the seeming vagaries experienced to date:

1. Following the hot rolling of uranium billets into rods, the rods were placed in a rack where they were permitted to cool to room temperature. Occasionally a rod

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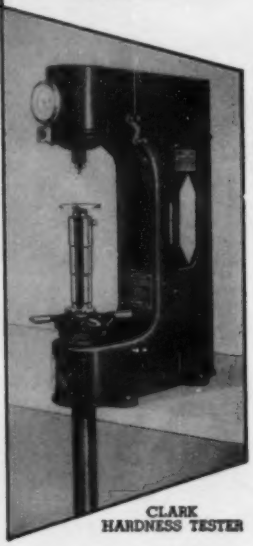

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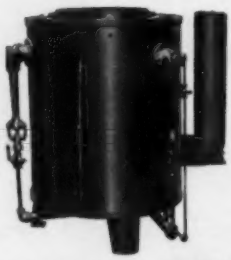

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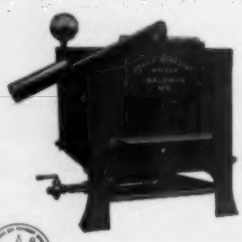

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Uranium . . .

would be encountered which would slowly increase in temperature until self-sustaining combustion was initiated and continued until all of the metal had burned to oxide.

2. A number of uranium pieces 0.5 in. thick were unintentionally exposed to heat from an external source for about an hour. The uranium ignited and continued to burn for almost a day.

3. During experimental research, two small batches of uranium powder appeared to have been rendered "nonpyrophoric" after treating the powder with carbon tetrachloride. When this was tried on a third batch, a violent explosion occurred.

4. After removal of loose uranium chips from a nitric acid bath, small localized spontaneous fires have been occasionally encountered. They have on many occasions been extinguished by applying water with a hose. Under confined conditions, similar fires have been extinguished by flooding with CO_2 or in extreme cases with argon — although in rare cases even the latter fails to extinguish the fire.

The above list partially illustrates the basis for the following tentative conclusions which were reached after study of the available circumstantial evidence:

1. Unusually high uranium pyrophoricity may be acquired as a consequence of factors associated with the initial preparation of the metal or it may be acquired at a later period because of metal exposure to air and moisture under quiescent conditions.

2. The presence of metal contaminants or existence of the metal in a stressed condition (lathe chips) tends to increase the probability that the uranium will acquire added pyrophoricity.

3. Spontaneous ignition of uranium involves a rapid initial exothermic surface reaction with air or water.

4. Pyrophoricity of uranium is strongly influenced by the nature of the surface oxide. Surface oxides acquired during metal exposure to dry air appear capable of materially reducing the ability of the metal specimen to acquire added pyrophoricity.

5. Low-density specimens of uran-

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Uranium . . .

ium metal prepared by decomposition of compressed uranium hydride are believed to have been involved in most known fires in which massive pieces of metal spontaneously ignited while at room temperature. However, uranium prepared by other powder metallurgical means will also occasionally display unusually high pyrophoricity.

Accepting the premise that uranium pyrophoricity can be increased as a consequence of metal exposure to water under suitable conditions, the following known reactions must be considered:

$$U + H_2O = UO_2 + 2\,H_2 \qquad (1)$$

There is no evidence that this exothermic reaction has ever taken place at room temperature at a rate sufficiently rapid to cause significant heating of the metal.

$$2\,U + 3\,H_2 = UH_3 \qquad (2)$$

This reaction has also been extensively investigated and could conceivably occur as a consequence of hydrogen evolved in reaction (1) above. There is little reason to believe this reaction could occur to

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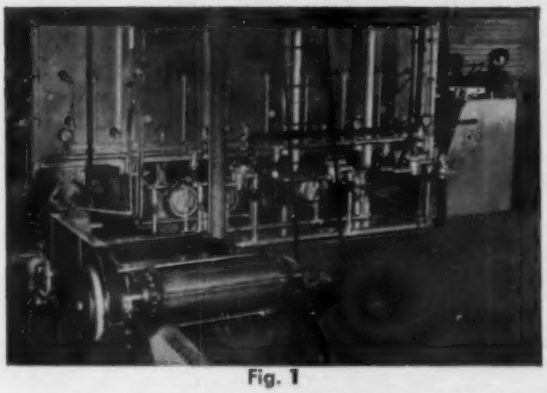

Fig. 1

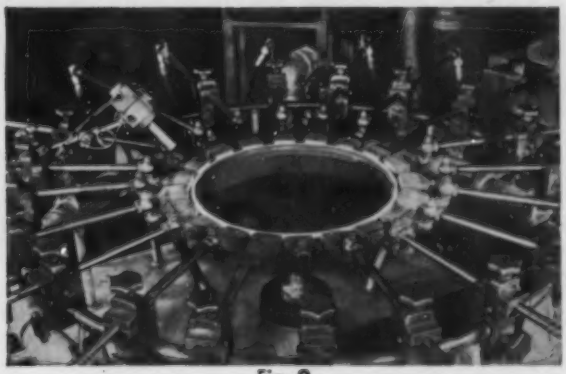

Fig. 2

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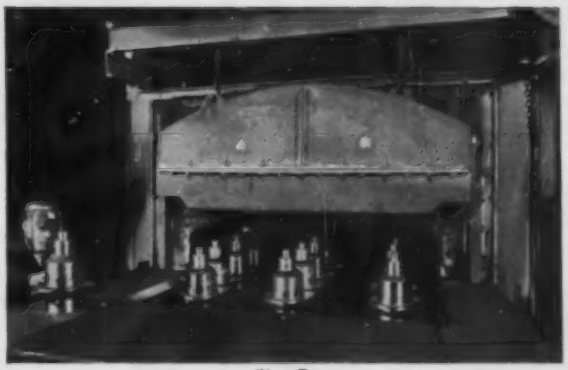

Fig. 3

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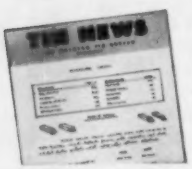

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Uranium . . .

any significant degree except under quiescent conditions tending to prevent immediate conversion of any UH_3 formed to UO_2.

$$2\,U + 2\,H_2O = UO_2 + UH_3 + \tfrac{1}{2}\,H_2$$

It is known that this reaction can occur at room temperature and that the reaction rate significantly increases with increased temperatures. Because of the known reactivity of UH_3 with air and water, one would expect its formation to be promoted under quiescent conditions.

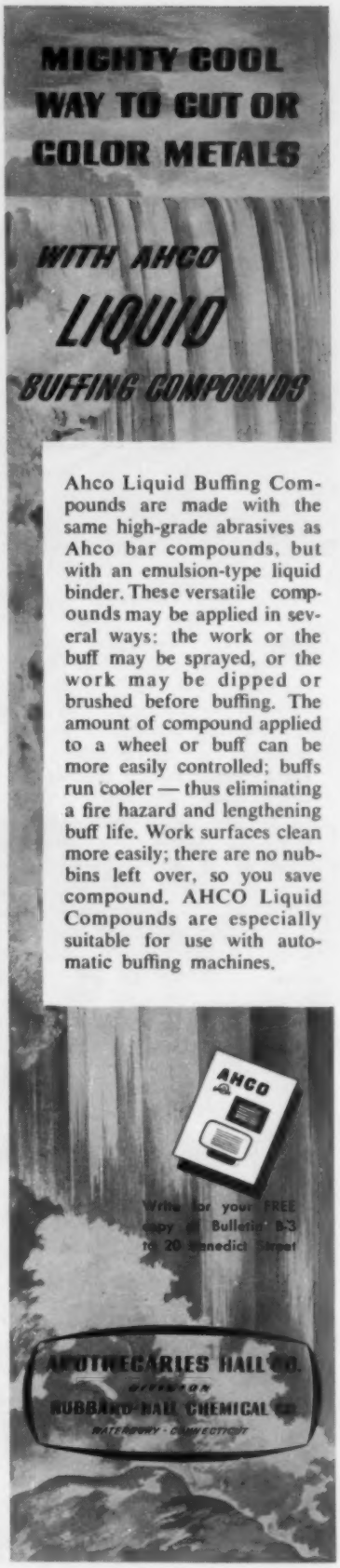
Formation of UH_3 on the metal surface could potentially increase uranium pyrophoricity by several mechanisms: In the first place, since UH_3 is formed in an extremely finely divided state, this could be thought of as pyrophorically equivalent to converting small pieces of metal into a form having a relatively enormously increased surface-to-mass ratio. Secondly, if the protective and relatively nonporous UO_2 film at the metal surface is replaced with a highly porous UH_3 coating, then such a change would increase the susceptibility of the surface metal to further attack by oxygen, hydrogen, or water.

Spontaneous combustion in uranium may be expected following an initial highly exothermic local reaction of UH_3 with air or water in which sufficient heat is rapidly created to raise the metal temperature in a local area to a point of permitting triggering of similar reactions over adjacent surfaces of the metal. It is suspected that the degree of pyrophoricity of massive uranium is at least partially governed by the quantity of dissolved or occluded hydrogen and hydride present in the metal at the time of its initial preparation.

A connection is thought to exist between factors tending to increase uranium pyrophoricity, factors involved in corrosion of uranium in water, and factors involved in water-metal explosions.

If the above line of thinking is confirmed in future research, it would be expected that one line of attack in preventing explosions would be to attempt to minimize the rate of hydrogen solution and of hydride formation at the surface of metal exposed to water.

D. F. RITCHIE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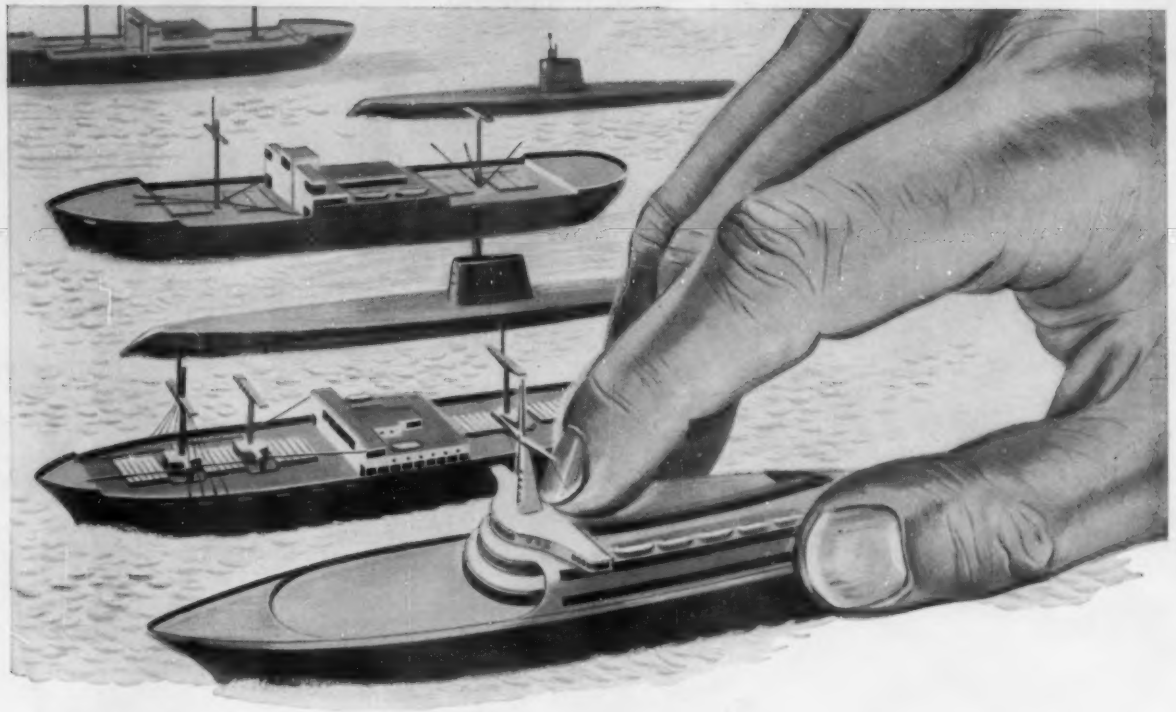

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Metals men who need better knowledge of titanium alloys—men who really *want* to get ahead in this new and promising field—cannot afford to miss the TITANIUM CONFERENCE! Through its Metals Engineering Institute, the American Society for Metals is conducting a five-day conference on present day problems in the *Titanium* field at Los Angeles, March 25 through March 29, 1957. This is a unique opportunity to get the latest information on titanium. Registration fee of $125 for the entire course covers daily lunches and study materials, which include the new ASM Titanium Course.

BRING YOUR THINKING UP TO DATE

There's still a lot that you can learn about titanium. The lectures offered at this conference, coupled with the exchange of ideas at three panel discussions will help to bring *your* problems into focus. Examine the topics at the left, and you will be convinced that the TITANUM CONFERENCE will help you modernize your thinking and improve your understanding of mechanical working, fabrication techniques, and new alloys, some of which have not yet reached the production stage.

LET'S TAKE ACTION

You should know what's going on in your field when it comes to titanium. Top men in the field will present informal lectures at the conference. Your next move should be clear—place your registration in the mail WITHOUT DELAY, or send for full information AT ONCE. Use convenient coupon.

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You'll earn and learn much more than the cost of your visit to the Metal Show. **You'll see nearly 500 exhibits** showing the most modern and cost-cutting ideas in the metals field. It'll be like a grand tour of the metals industry, which would take months to see in any other way.

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MORE THAN 100 TECHNICAL PAPERS are scheduled. Specialists will discuss their most recent findings. They will tell you what's new and coming in the metals field and how you can profit most from these modern achievements.

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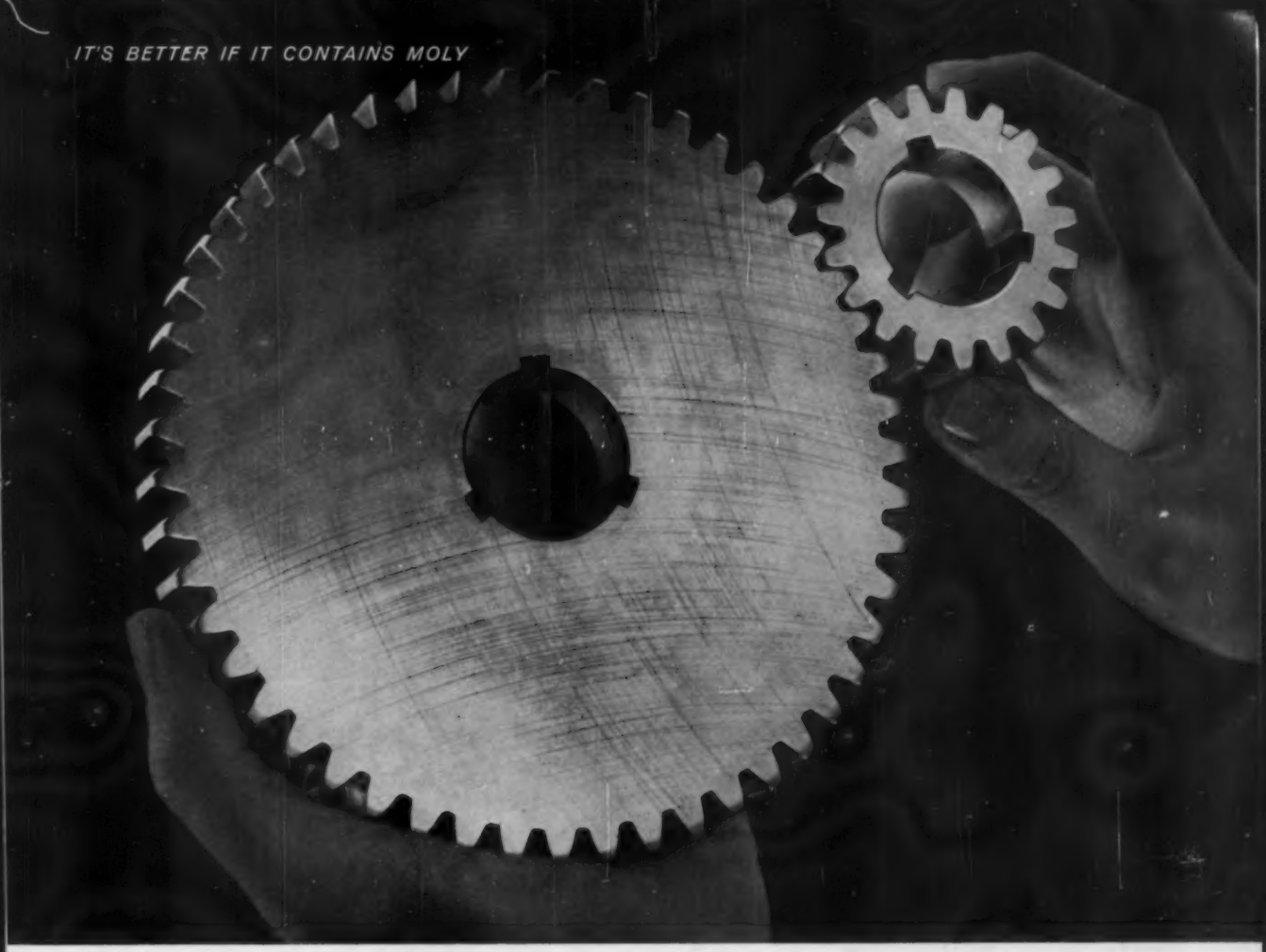
IT'S BETTER IF IT CONTAINS MOLY



Up to 1% Moly in carburizing steels gives required hardenability economically

Why limit the use of molybdenum to the .15/.25% Mo and .20/.30% Mo contents of the traditional grades? For the contributions of moly do not stop there. Laboratory tests and production runs prove that as molybdenum contents increase up to 1%, hardness increases progressively. A wide range of case and core hardenabilities, therefore, can be obtained – economically, too.

Tests with a series of molybdenum-manganese steels show that these compositions give higher case hardness on a direct quench than other steels of comparable core hardenability. One extensively tested composition, for example, is 0.5% Mo – 0.5% Mn steel. It shows longer life, and is lower in cost than steels previously used. And it produces a higher case hardness with similar or less distortion. What's more, tool life and surface finish are equal or better. Good reasons why several companies have already adopted this grade for automotive gears and other critical applications.

If you use carburizing steels, see what a higher molybdenum content can do for you. Part of the story is contained in the technical article "New Carburizing Steels For Critical Gearing." For your copy, or other technical data, write Climax Molybdenum Co., Dept. 5, 500 Fifth Avenue, New York 36, N. Y.

CLIMAX MOLYBDENUM

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U.S.I. CHEMICAL NEWS

A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries

Greenleaf to Handle Market Development of Zirconium And Titanium for U.S.I.

William C. Greenleaf has been named Manager of Metals Development for U.S.I. and will be responsible for market development and sales of zirconium and titanium sponge, to be produced from U.S.I.'s two new plants now being built in Ashtabula, Ohio.

A recognized authority in the field of zirconium and titanium, Mr. Greenleaf presented three papers during the 1955 Atomic Industrial Forum Zirconium Program, describing (1) melting of zirconium, (2) fabrication of zirconium, and (3) zirconium mill products and prices. He also conceived and developed processes now in general use for producing both wide-sheet and flat-bar titanium and zirconium by continuous strip-mill techniques.

Faye Named Manager of Sodium Product Sales

Martin Faye has been named Manager of Sodium Product Sales for U.S.I. and will be responsible for coordinating sales and sales promotional activities for metallic sodium, "U.S.I. Isosebacic" acid and related products.

Mr. Faye joined the U.S.I.-National Distillers organization in 1952 in the Market Research and Development Department.

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing the Editor, U.S.I. Chemical News.

A zirconium-copper alloy now available is reported to combine high electrical conductivity with good strength retention at elevated temperatures. Suggested for electrical motor commutators serving above 500°F where strength is needed. Conductivity is 95.8% of copper. **No. 1193**

Titanium wire cloth is now on the market in sizes from 60 mesh to coarser grades. It is reported to be particularly suitable for filtering or screening highly corrosive materials. **No. 1197**

Zirconium and Titanium Lick Roughest Corrosion Problems

Metals to be Available at Lower Cost in Future; Provide Long-Lived Materials of Construction; Complement Each Other on Corrosion Resistance

It is now practical to fabricate equipment which is *corrosion-resistant to almost every substance encountered in industry*, by using either zirconium or titanium metal. Alloys of either metal, or possibly both, may extend the range even further.

Industrial applications of these metals have been hampered by two considerations: availability and price. Zirconium will shortly be produced at a rate sufficient to supply industrial needs, and titanium has been available to industry during the past two years. And it is expected that increased production of these metals during the next few years will result in significant price decreases.

Twelve to thirteen thousand tons of titanium were available in 1956 and present construction schedules indicate that the figure will rise substantially in 1957. U.S.I.'s new plant alone will add 5,000 tons to the annual production capacity by the end of the year. Zirconium will be on the market in quantity by mid-1957. When its new plant at Ashtabula, Ohio gets under way, U.S.I. will be able to supply 500,000 pounds or more per year to commercial users in addition to its Atomic Energy Commission commitments of 1,000,000 pounds per year.

New Metals Economical

Chemical process equipment can now be fabricated from titanium for a little over twice the price of stainless steel, and it is expected that in the future titanium equipment will be only 50-75% higher than stainless. Commercial grade zirconium equipment will probably be priced only 75-100% higher than stainless when volume production is reached.

Typical Corrosion Resistances* of Zirconium and Titanium

Corrosive Media	Metal Resistance	
	Zirconium	Titanium
Sulfuric Acid	excellent to good below 80%	good below 5%
Nitric Acid	excellent	excellent
Hydrochloric Acid	excellent	good below 10%
Phosphoric Acid	excellent to fair below 85%	poor
Chromic Acid	excellent	excellent to good
Aqua Regia	poor	excellent
Wet Chlorine Gas	poor	excellent
Chlorine Water	excellent	excellent
Sodium Hydroxide	good below 90%	good below 50%
Ferric Chloride	poor	excellent
Calcium Chloride	excellent	excellent
Cupric Chloride	poor	excellent
Sodium Chloride	excellent	excellent
Ammonium Chloride	excellent	excellent
Aluminum Chloride	excellent	excellent to fair

*Above data do not cover all conditions because of space limitations. Literature references may be obtained by writing the Editor, U.S.I. Chemical News, 99 Park Ave., N. Y. 16, N. Y.

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HOW TO CONTROL ATMOSPHERES...

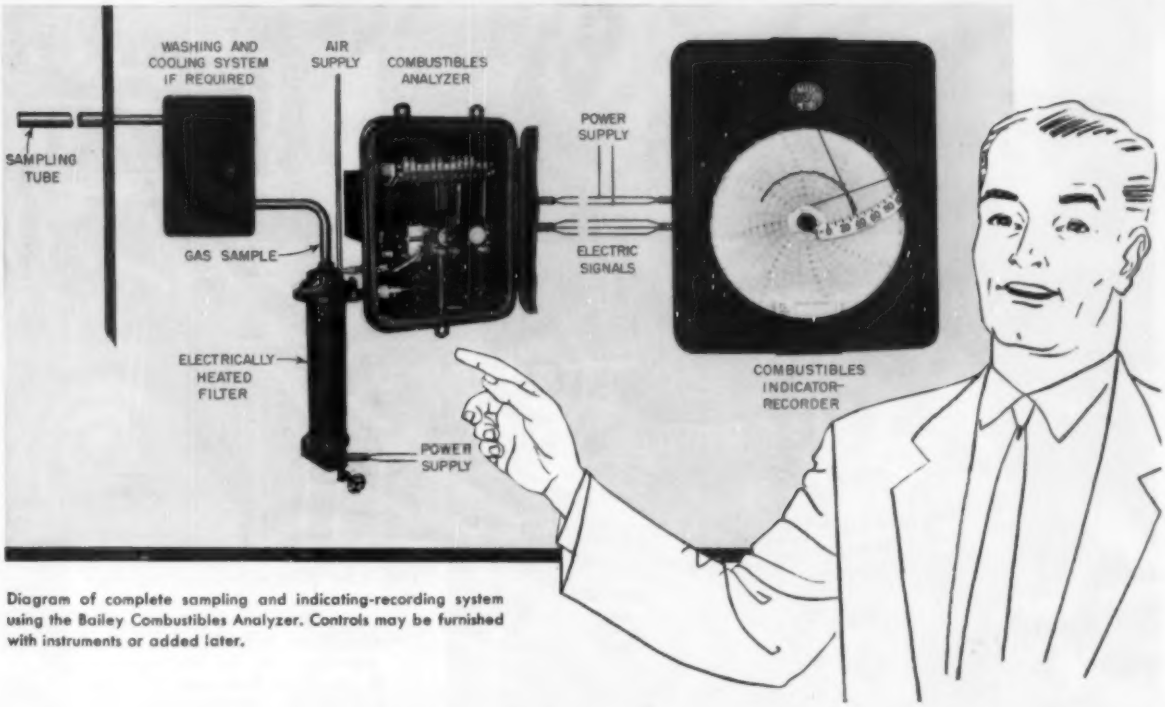

Diagram of complete sampling and indicating-recording system using the Bailey Combustibles Analyzer. Controls may be furnished with instruments or added later.

BAILEY COMBUSTIBLES ANALYZER

improves steel quality, saves gas

Whether you are doing bright annealing, hardening, normalizing or carburizing, keeping a constant watch on your atmospheres with a Bailey Combustibles Analyzer will help you do a better job at lower cost. This instrument provides a continuous measurement of the per cent combustible in the protective atmosphere gasses. It operates a remote electronic receiver for indicating, recording and controlling.

The Bailey Combustibles Analyzer monitors the quality of atmosphere gas. When the quality changes, as shown by changes in the per cent combustibles, the Analyzer operates a pneumatic controller which automatically controls the fuel rate. By maintaining the proper gas-air mixture, the uniformity of the atmosphere—and of the final steel product—is protected.

An important use for the Bailey Analyzer is in furnace purging—necessary to prevent explosion during startup. The instrument tells the operator when the combustibles have been reduced to a point where it is safe to start up the furnace. Without a Bailey Analyzer, purging is usually done strictly on a time basis, a procedure that is wasteful and unsafe.

Put the Bailey Combustibles Analyzer to work as a watchdog and control on your atmosphere generators and heat treating furnaces. It is the one way you can be sure you are maintaining the atmospheres specified by metallurgists for your processes.

Your Bailey Engineer will show you how you can use this instrument to improve steel quality and save gas. Or, write to our Iron & Steel Division for Product Specification E65-3 with complete details. 58-1

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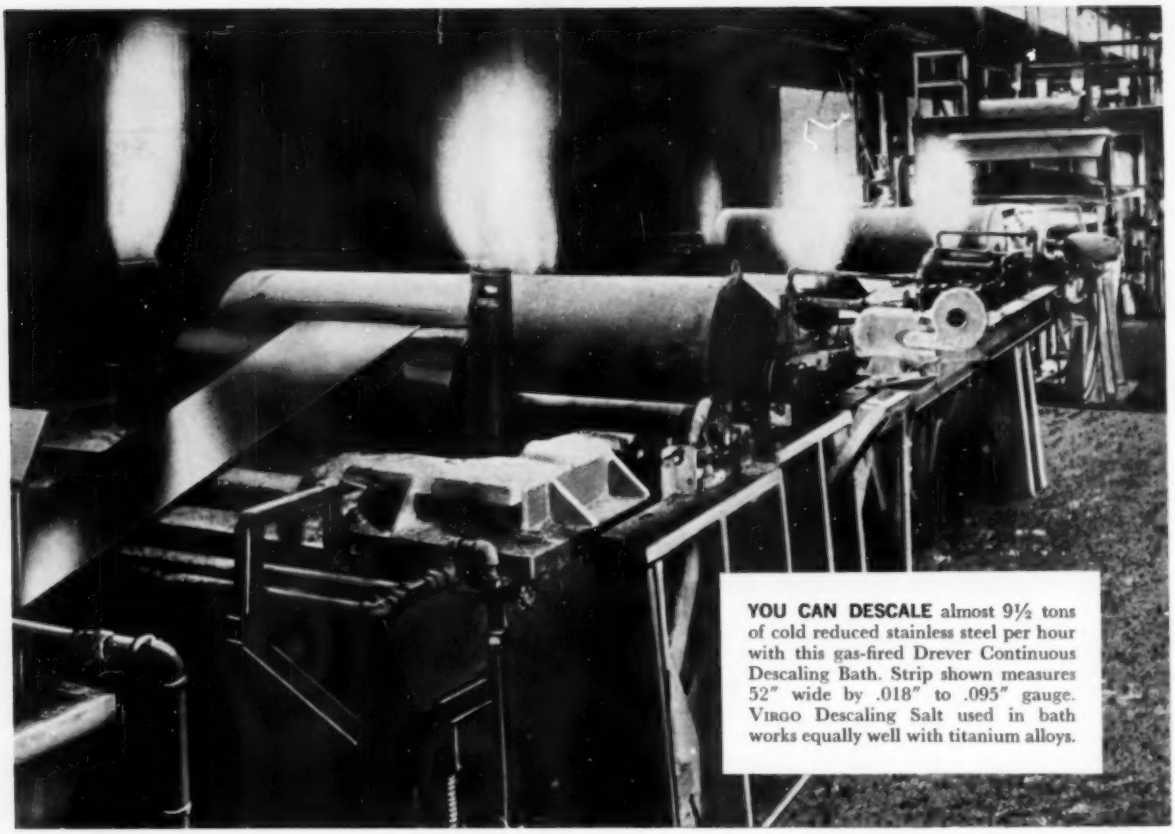

YOU CAN DESCALE almost 9½ tons of cold reduced stainless steel per hour with this gas-fired Drever Continuous Descaling Bath. Strip shown measures 52″ wide by .018″ to .095″ gauge. VIRGO Descaling Salt used in bath works equally well with titanium alloys.

VIRGO® SALT descales 18,700 lbs. of stainless strip in one hour

You, too, can accelerate your descaling speed to synchronize with production, when you use VIRGO Descaling Salt.

Equally important are the economy and safety you get when you use VIRGO.

Steel and titanium—one bath • You can descale both stainless steel and titanium alloys with the same salt bath.

Fast • The salt is so effective in making surface coatings acid-soluble, that you can remove the coating in one-tenth to one-hundredth the usual pickling time.

Safe for metals • VIRGO Descaling Salt reacts only with scale—and with no loss of base metal. There is no danger of hydrogen embrittlement when descaling titanium.

Safe for personnel • The VIRGO bath is simple and safe to operate when normal precautions are observed. Bath temperatures range from 800° to 1250°F., depending on the application.

Any form • Descale strip, sheet, bars, wire, tubes, or any other form to a chemically clean surface.

Acid disposal less of a problem • You can reduce the problems of spent acid disposal since the VIRGO process decreases acid consumption.

To find out more specifically how VIRGO Descaling Salt gives you bright, clean surfaces—at speeds to match your production requirements—write for Bulletins 25 and 25-T, stating the application you are considering.

Help for your metal cleaning operations

Get the benefit of Hooker's basic chemical experience for your metal cleaning operations. Make Hooker your source for chemicals if you're:

Desanding • Use VIRGO Electrolytic Salt to remove sand, graphite, other impurities —produce a chemically clean surface.

Reclaiming parts loaded with carbon or rust • VIRGO Molten Cleaner works fast—is the quick answer for large-scale salvage operations.

Vapor degreasing • You get unique stability—degrease more parts between cleanouts—using NIALK® TRICHLOREthylene with **psp** (permanent staying power).

Stripping, acid neutralizing • You can get Hooker caustic soda in *four* convenient flake sizes, in new easy-to-empty drums with 18″ openings.

Acid cleaning, pickling • You can get Hooker muriatic acid in 4,000-, 6,000-, or 8,000-gallon tank cars.

Plating with tin-zinc, tin, silver, copper • Get the benefit of more than 50 years' experience in potash production, when you specify NIALK® caustic potash for your plating operations.

For literature on any of these Hooker Chemicals for metals, just write us on your business letterhead.

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Large OD Thin Wall Tubing offers New Answers to Design Problems

Superior specializes in an unusually wide range of analyses, shapes and sizes

Today's design engineers are finding large OD thin wall tubing by Superior answers more and more of their design problems. Its light weight makes it ideal for ducting, fuel and oil lines in aircraft. Thin wall tubing also functions efficiently as a low pressure heat exchanger tube. Because of its close tolerances, ductility, and bright, clean OD and ID surfaces, Superior thin wall tubing is an excellent choice for flexible metal hose for the food, chemical and aircraft industries. Other applications include bellows, solenoid cylinder cores, cylinder liners for automobile hydraulic brakes, fractional horsepower motor casings, ceramic drills, electron power tube anodes and cathodes, and casings for radioactive well logging instruments.

A number of analyses in large OD thin wall seamless and Weldrawn® tubing are available at Superior. Stainless, carbon and alloy steels, beryllium copper, titanium, nickel and nickel alloys are offered in sizes up to 1⅛" OD with .035" wall maximum; Monel and certain analyses of stainless steel in sizes to 2½" OD with .025" wall maximum.

Superior tubing can be supplied in random, multiple or cut lengths up to 30 feet, and in any of three standard tempers (fully annealed, soft; half-hard drawn; full-hard drawn) or in special tempers required by Government, aircraft and customer specifications. Thin wall tubing can be shipped in special cardboard cylinders, to protect it from dents and scratches.

For additional information, get your free copy of Data Memorandum No. 4. Write to Superior Tube Company, 2008 Germantown Ave., Norristown, Pa.

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SPECIAL REPORTS ON FINISHING NON-FERROUS METALS

NUMBER III—Lustrous, Corrosion-Resistant Finishing with Chemical Polishing Iridite®

WHAT IS IRIDITE®?

Briefly, Iridite is the tradename for a specialized line of chromate conversion finishes. They are generally applied by dip, some by brush or spray, at or near room temperature, with automatic equipment or manual finishing facilities. During application, a chemical reaction occurs that produces a thin (.00002" max.) gel-like, complex chromate film of a non-porous nature on the surface of the metal. This film is an integral part of the metal itself, thus cannot flake, chip or peel. No special equipment, exhaust systems or specially trained personnel are required.

Chromate conversion coatings are widely accepted throughout industry as an economical means of providing corrosion protection, a good base for paint and decorative finishes for non-ferrous metals. Certain of these coatings also possess chemical polishing abilities that have luster-producing, as well as corrosion-inhibiting, effects on zinc and cadmium plate, zinc die castings and copper alloys. However, continued developments in this field have been so rapid that many manufacturers may not be completely aware of the breadth of application of this type of finish. Hence, this discussion of the many ways in which this chemical polishing characteristic can be used in final finishing or pre-plating treatments to produce a lustrous appearance with distinct display and sales appeal and appreciable savings in cost. Report I on decorative, corrosion-resistant finishes and Report II on paint base corrosion-resistant finishes are available on request.

The degree of luster possible on a surface is a function of the degree to which the surface can be smoothed. Leveling to provide a smooth surface can be achieved by mechanical or chemical means, or a combination of these, depending upon the luster desired and the original condition of the metal. Chemical polishing effectively imparts luster otherwise difficult and costly to obtain. For this reason, it is often used to supplement or entirely replace mechanical polishing, depending upon the application and the original condition of the metal. Chemical polishing has the additional advantage of providing overall treatment of the submerged part. It reaches into even the deepest corners and recesses that are otherwise inaccessible. Certain of the Iridites are specifically designed to perform this chemical polishing operation. Also, they provide corrosion protection as do all Iridites, thus may be used as a final finish or a pre-plating polish.

If Iridite is to be used as a final finish, in contrast to pre-plating treatment, the chromate conversion coating generated is allowed to remain, providing good corrosion resistance. Color inherent in these Iridite films ranges from a yellow cast to yellow iridescent. These coatings may be used without further treatment where this color is acceptable and good corrosion resistance is desired. Further, these basic coatings can be tinted by dyeing. Among the dye tints available are shades of red, yellow, blue and green. If desirable, the basic coatings can also be modified by a bleach dip leaving a clear bright or blue iridescent finish. In all cases bleaching reduces corrosion resistance.

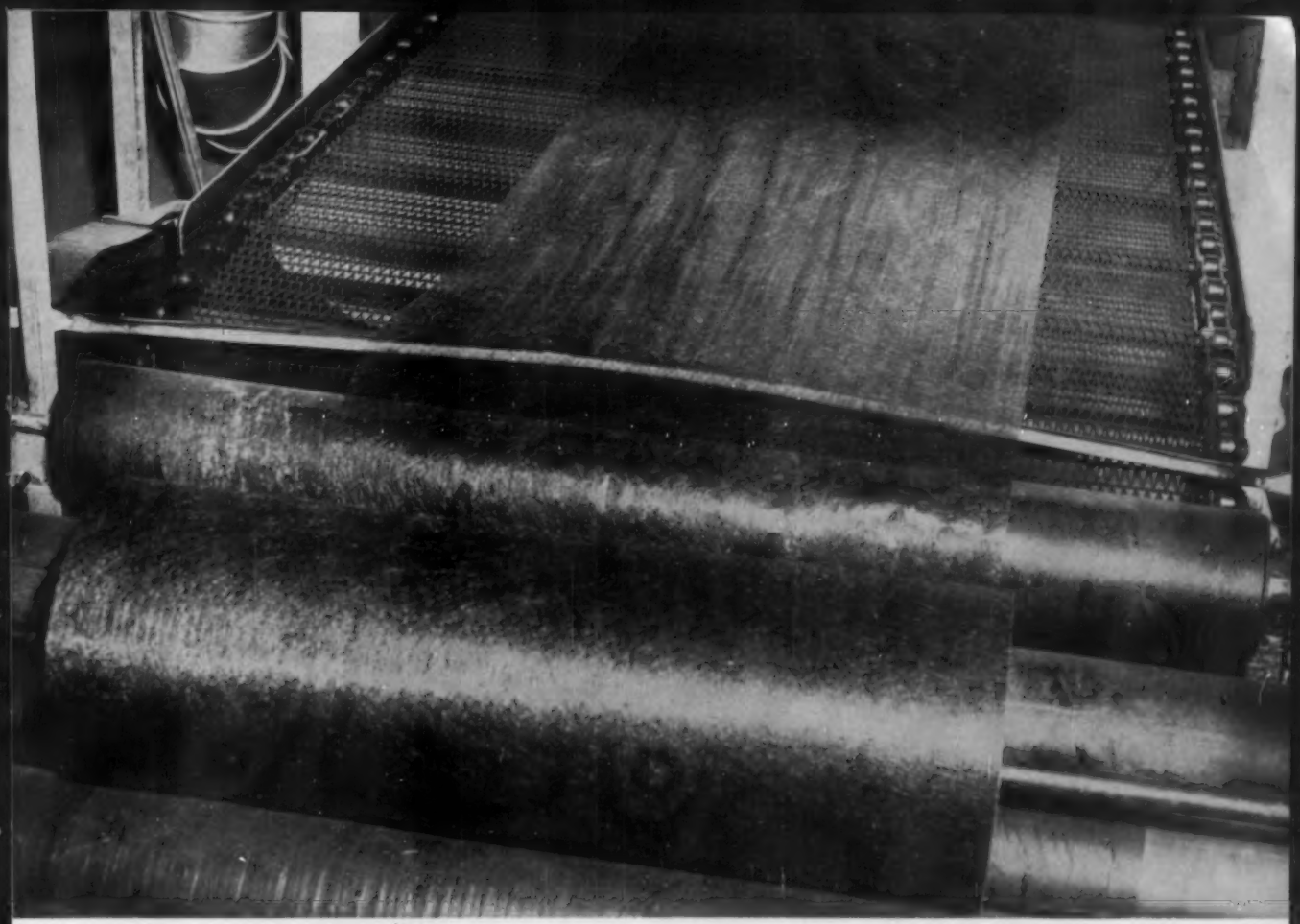
As examples of this type of final finishing, Iridites #4-73 and #4-75 (Cast-Zinc-Brite) make possible for the first time, lustrous chemical polishing of the as-cast surface of zinc die castings. Thus, in many cases, sizeable savings in finishing cost are realized by elimination of plating costs. This economical method can be used on tools, appliance parts, toy pistols, locks and many other small castings. Another example is the treatment of copper and brass parts, such as welding tips, to eliminate buffing and provide additional corrosion resistance. In many cases, handling costs are reduced appreciably by replacing piece-part handling with bulk processing. Still another example of the use of this chemical polishing and protective quality of Iridite is a simple system of zinc plate, Iridite and clear lacquer instead of more costly electroplated finishes. Typical of this type of lustrous finish are builders hardware and wire goods.

As a pre-plating treatment, in contrast to final finishes, Iridite can be used to chemically polish zinc die castings or copper prior to plating. In such cases, Iridite should be applied as an in-process step, so that the protective film is removed before the plating cycle. The savings in handling, material and labor costs are obvious. This process has made it practical to plate chrome directly over copper on steel, conserving nickel, yet producing a lustrous chrome finish. Used after stripping faulty plate in reprocessing zinc die castings, Iridite restores luster to the casting, thus making possible replating without blistering.

Other Iridite finishes are available to produce maximum corrosion resistance, a wide variety of decorative finishes and excellent bases for paint on all commercial forms of the more commonly used non-ferrous metals. As a final finish, appearance ranges from clear bright to olive drab and brown and many films can be bleached or dyed. As a paint base Iridite provides excellent initial and retentive paint adhesion and a self-healing property which protects bare metal if exposed by scratching. Iridites have low electrical resistance. Some can be soldered and welded. The Iridite film itself does not affect the dimensional stability of close tolerance parts.

Iridites are widely approved under both Armed Services and industrial specifications because of their top performance, low cost and savings of materials and equipment.

You can see then, that with the many factors to be considered, selection of the Iridite best suited to your product demands the services of a specialist. That's why Allied maintains a staff of competent Field Engineers—to help you select the Iridite to make your installation most efficient in improving the quality of your product. You'll find your Allied Field Engineer listed under "Plating Supplies" in your classified telephone book. Or, write direct and tell us your problem. Complete literature and data, as well as sample part processing, is available. Allied Research Products, Inc., 4004-06 East Monument Street, Baltimore 5, Maryland.



This Wissco Balanced Spiral Belt, in constant use 24 hours a day and five days a week, carries glass fiber mats through a 650°F drying oven at speeds up to 50 feet per minute.

WISSCO BELTS *and the Texas Glass Fiber Corporation*

The story of Wissco Belts is best told by their users. For instance, Texas Glass Fiber Corporation of Grandview, Texas, reports:

"The installation of a Wissco Belt speeded up our glass-curing operation by 250%!"

This Wissco Belt is used in drying glass fiber mats impregnated with phenolic resin bonding material. The company's president, Mr. W. E. Hutton-Miller, reports: "Before we switched to Wissco Belts, this operation slowed up our production considerably.

"With our old, close-mesh belt, the lack of adequate circulating air greatly retarded the maximum flow rate through our drying oven. For instance, in drying glass air filter material, the greatest speed possible was 10 feet per minute. What's more, dripping resin continually clogged the small mesh holes, making it necessary to remove these deposits by banging the belt with a hammer. This, of course, did not do the life expectancy of the belt any good.

"Then a Wissco technical representative visited Texas Glass Fiber. He recommended that we change to an open-mesh Wissco Balanced Spiral Belt. Not only did the open mesh of this belt enable the fiber glass material to dry faster, but it also prevented dripping resin from clogging the belt.

"As a result, we were able to increase our belt speeds for air filter drying to 35 feet per minute. We find Wissco Belts superior in every respect to the belts we formerly used. In addition to increased production, these belts have brought us definite maintenance and replacement savings," Mr. Hutton-Miller concludes.

So—no matter what kind of operation yours is—it'll pay you to get the complete story on Wissco Belts, as well as free Wissco technical help, from our nearest sales office soon.

THE COLORADO FUEL AND IRON CORPORATION
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THE COLORADO FUEL AND IRON CORPORATION

4548

how Vacuum Metals FERROVAC solved critical surface problem for Bausch & Lomb . . .

The jewelers' rolls Bausch & Lomb use to roll gold-alloy wire for eyeglass frames must be *mirror-smooth*. Rolls of conventional air-melted alloys just didn't work out economically. A normal amount of nonmetallic inclusions in the metal meant they had to be ground and reground, polished and repolished, before the surface was satisfactory. And even then, many rolls had to be scrapped when finishing uncovered inclusion pits.

The solution to this problem proved to be Vacuum Metals FERROVAC® Airdi 150. A better finish was obtained without any regrinding—and the number of scrapped rolls fell to zero. Here's why: Vacuum-melting removes the gases which create nonmetallic inclusions in the molten metal before they get into the product. This means cleaner metal, smoother surfaces. What's more, vacuum-melting improves fatigue, creep and impact strengths . . . reduces brittleness.

Vacuum-melted metals are the answer to jobs where surface is critical—like gauge blocks, plug and ring gauges, rolls for aluminum foil—as well as many other specially demanding applications. They're available in most grades and sizes, including special ferrous and non-ferrous alloys. Write now for a free analysis sheet on which to describe your application. It will help us both decide how vacuum-melted metals can serve you best. *Vacuum Metals Corporation, Division of Crucible Steel Company of America, P. O. Box 977, Syracuse 1, New York.*

VMC®

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Division of Crucible Steel Company of America

Exclusive with the Heroult:

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The Heroult is the only electric furnace on the market with a cage-type shell. In this exclusive design, the shell plates are loosely attached to a heavy structural supporting cage, which allows the plates to expand and contract freely, thus minimizing shell distortion due to extreme changes in temperature. This type of construction also permits easy replacement of damaged shell plates.

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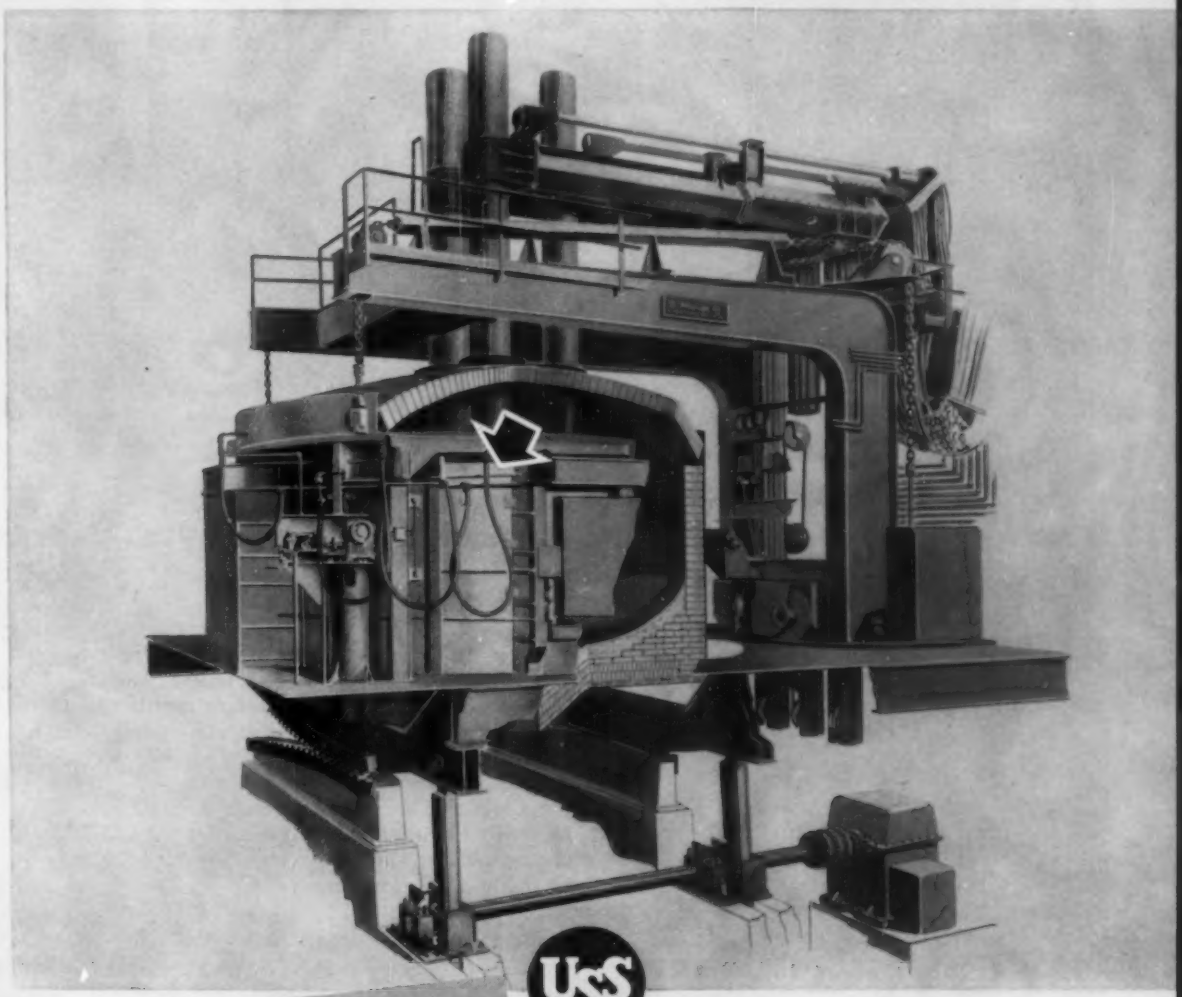

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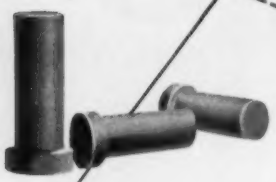

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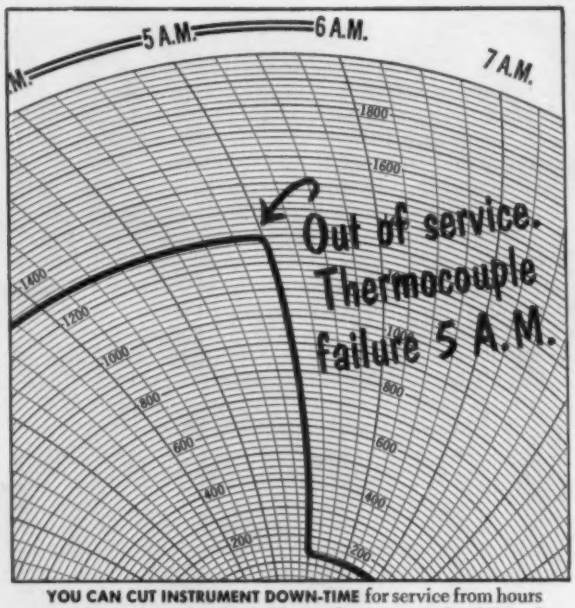

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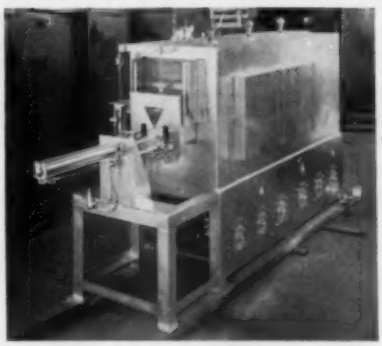

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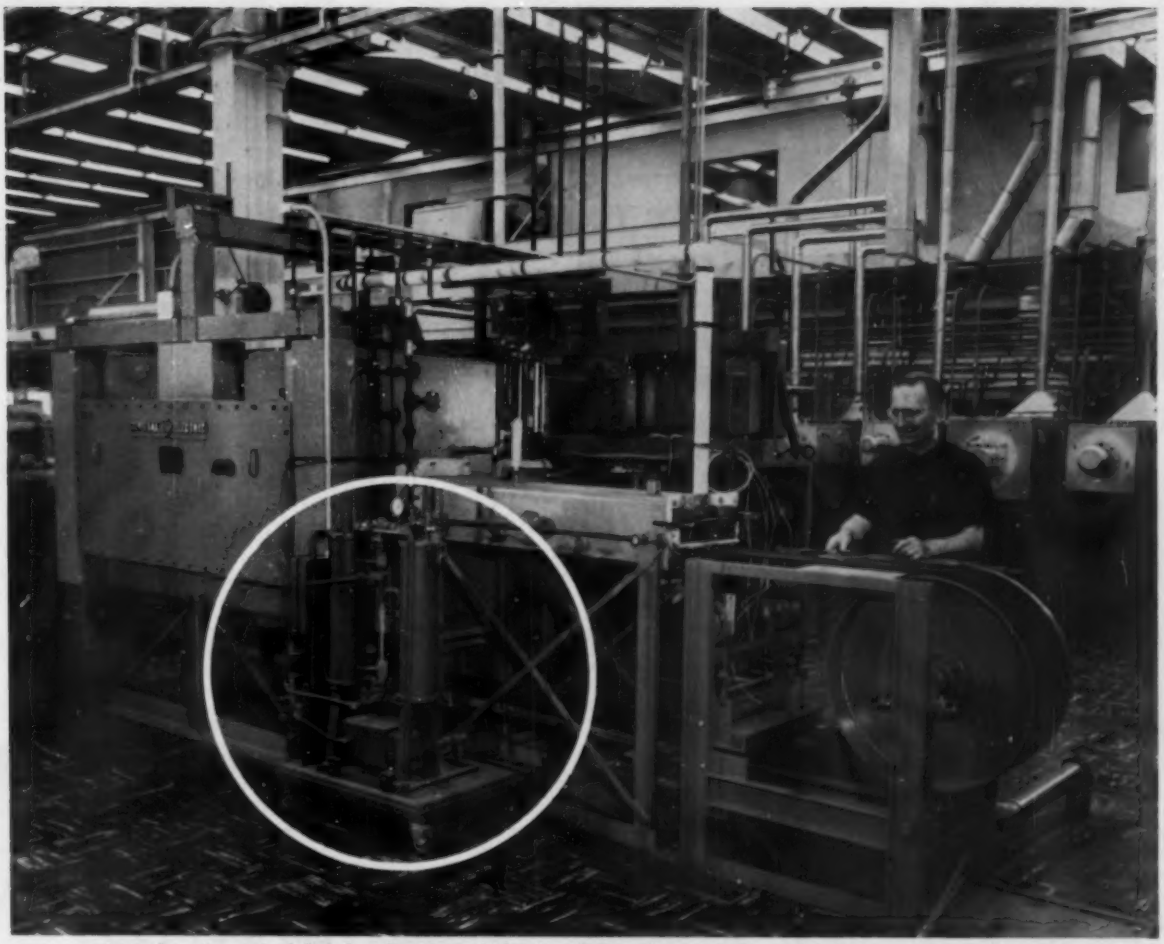

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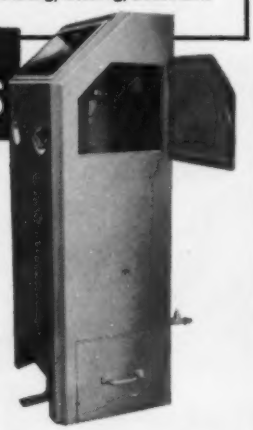

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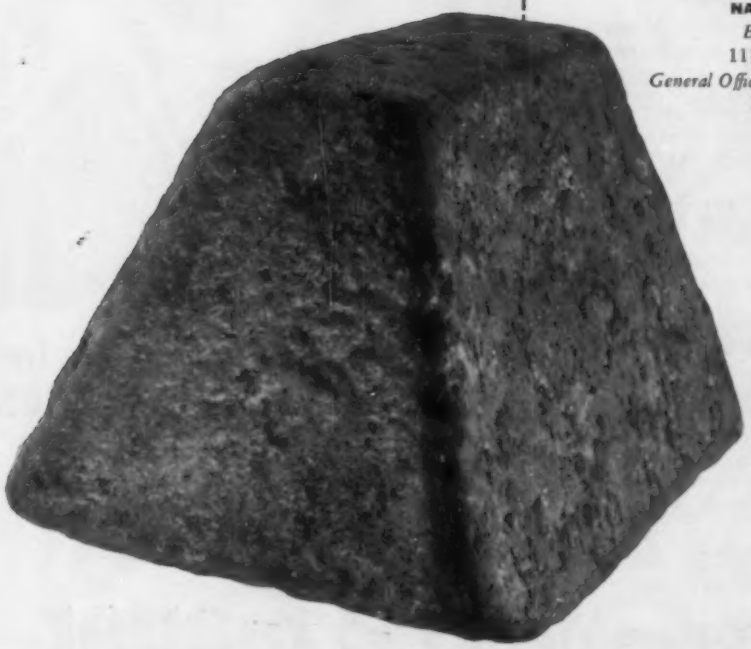

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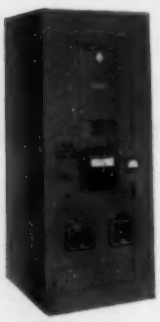

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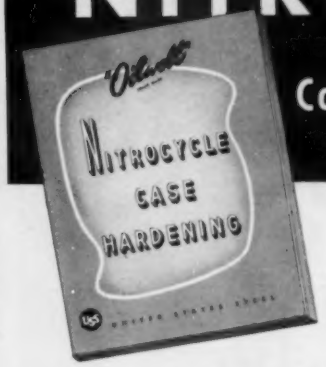

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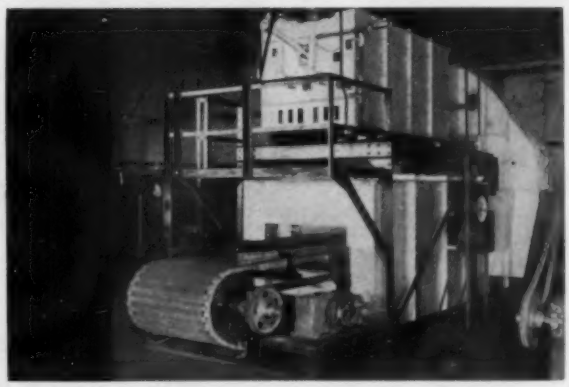

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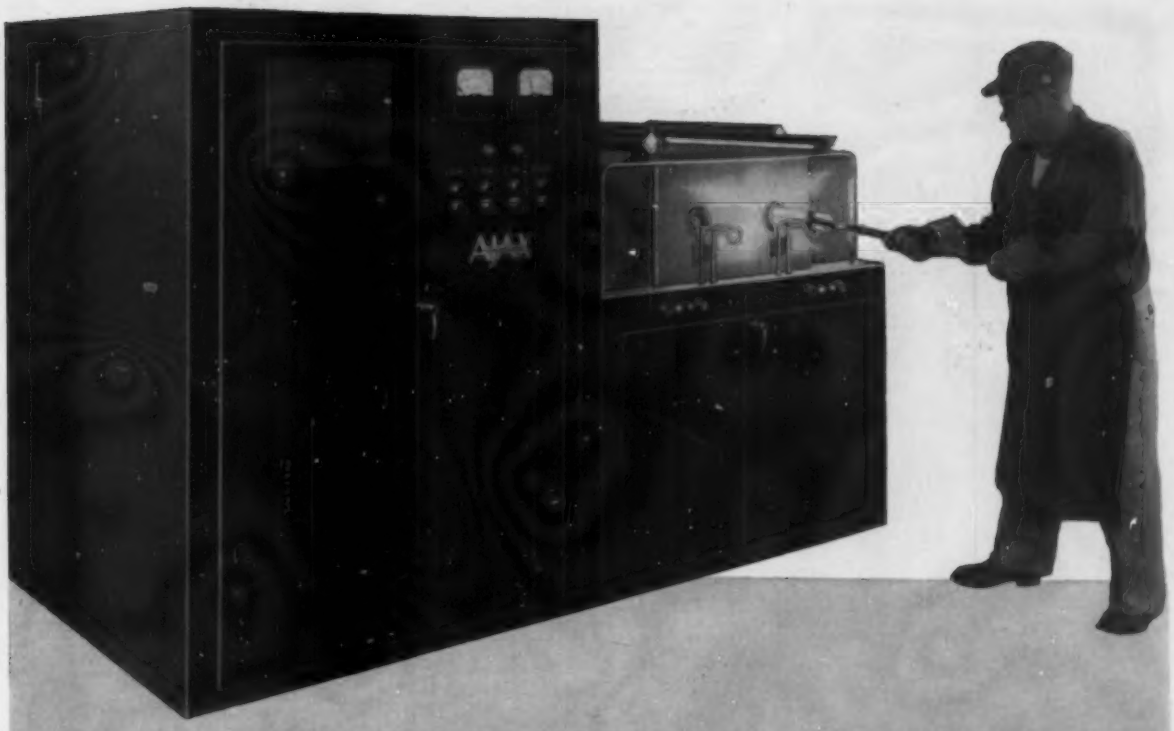

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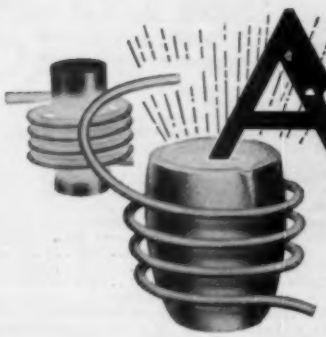

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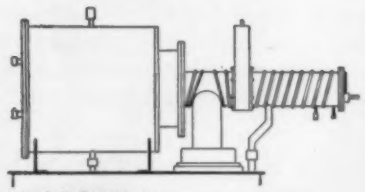

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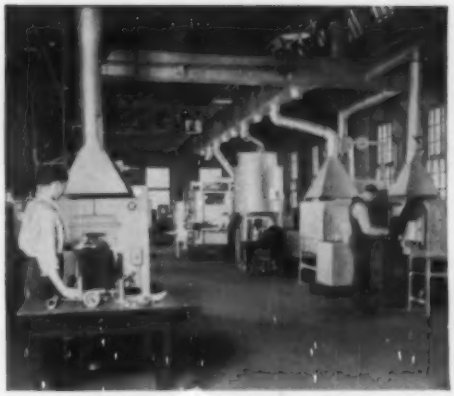
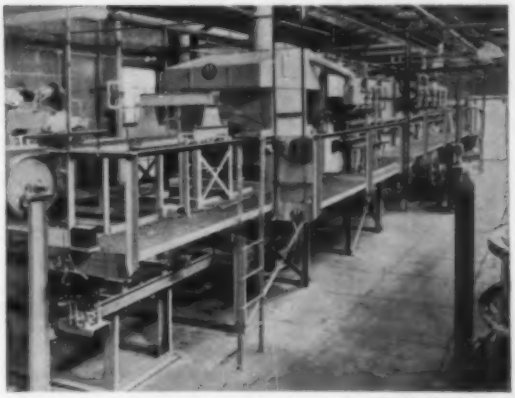


General view of the research department showing several of the continuous and batch type experimental furnaces.



View of combination gas-fired and electric continuous furnace equipped with flame preheating burn-off or oxidizing section and controlled heating, soaking and cooling zones, for producing various surface conditions on strip.

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